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OBSERVATIONS ON THE RASPBERRY CANE MIDGE (*THOMASINIANA THEOBALDI* BARNES)

III. CONTROL

By R. S. PITCHER

East Malling Research Station, Kent

THE Raspberry Cane Midge is principally important as a precursor of the fungal disease "Midge Blight". This disease may kill a substantial proportion of the canes of varieties such as Newburgh and Malling Enterprise before they can bear fruit in the following spring (Pitcher and Webb, 1952) ; in addition, the yield of many of the surviving canes is reduced. Fortunately the midge is not a universal pest of raspberries ; in Britain its range is restricted to the south and the Midlands and several varieties, such as Norfolk Giant and Malling Landmark, are highly resistant.

With the exception of Theobald (1921, unpubl.), who recommended nicotine sulphate for the control of the midge larvae and lime sulphur for the fungi which followed, the early workers took no account of the fungal associations. Soil applications of naphthalene or calcium cyanide were recommended by Barnes (1926, 1927) and cultivation by Barnes (1931) and Massee (1940). Fox Wilson and Green (1944), however, recognized that fungal pathogens were also involved but were unable to control them with Bordeaux mixture. In small-scale trials they controlled the larvae of the first midge generation with nicotine and obtained promising results from a soil application of naphthalene. In a preliminary experiment carried out at East Malling in 1945, four applications of DDT at 0·05 per cent. gave good control of the first generation but not of the second ; lime sulphur failed to control either midge or fungi. DDT was also used successfully by Pyenson (1946) and Runyon (1945) for the control of the Boxwood Leaf Miner and subsequently Bachmann (1950) has achieved control of the Raspberry Cane Midge in Switzerland with soil applications of BHC or chlordane.

From April, 1946, to September, 1948, the Agricultural Research Council made a special grant to finance an investigation of the biology and control of the Raspberry Cane Midge. The present paper describes the experiments on control, which are considered under the following headings :

(1) Insectary trials, yielding information on the suitability and mode of action of certain insecticides ;

(2) Field trials, carried out from 1947-50 inclusive, at first following some of the recommendations of previous workers and later using new materials and techniques and incorporating the experience gained from the insectary trials and the early field experiments.

INSECTARY TRIALS.

In small-scale preliminary tests carried out in 1946-48, neither BHC, DDT, nicotine nor derris showed any marked ovicidal or larvicidal properties but BHC,

chlordane and DDT, in the form of deposits on cut raspberry canes, were toxic to active midges within 18 hours, BHC and chlordane being significantly more active than DDT. Subsequent trials therefore sought to estimate the effect of these and other materials firstly on ovipositing midges and secondly on eggs and larvae.

Effect of insecticides on oviposition.

In the field, newly-emerged midges lay their eggs under the outer cortical tissues of young green canes, usually where the epidermis has split naturally (Pitcher, 1952). Trials were undertaken to find if oviposition could be inhibited by spraying the cane with insecticide prior to the emergence of the midges. BHC, DDT and parathion were used, so formulated that the diluted wash of each contained 0·05 per cent. of anhydrous *cyclo* hexylamine dodecyl sulphate and 1·0 per cent. of diacetone alcohol with 0·025 per cent. of dioctyl sodium sulphosuccinate as a wetter ; in this paper formulations of this type will be termed " emulsions ". In nearly every instance a comparison was made with the wettable powder formulations of BHC and DDT used in the field trials. After the insecticides had been applied, artificial slits were made in each cane and the outer cortical tissue raised at one side so that each treatment offered a free and equal opportunity for egg laying (see Fig. 1). Active midges

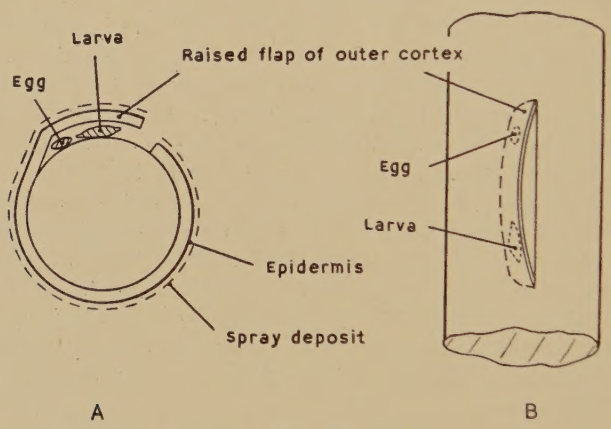

FIG. 1.

Diagram of artificial slits made in canes used in insectary trials.
A. In transverse section.
B. In elevation.

were then released in the compartment and, after about 48 hours, the canes were removed and the eggs on each were counted. The records of these trials are summarized in Table I.

In individual trials, because of the high degree of variability, no one treatment differed significantly from the untreated control at the 5 per cent. level but, over the whole series, the emulsion formulations of BHC and DDT gave a significant degree of control, although the wettable powders did not. Thus, although some treatments showed slight inhibitory powers, none gave an adequate degree of protection against oviposition by active midges.

TABLE I.

Number of eggs laid by T. theobaldi *on raspberry canes treated with insecticide.*

Trial no.	Date of Application (1948)	Gamma BHC			DDT			Parathion 0·05%	Control
		Concn. %	Emuls.	W. powder	Concn. %	Emuls.	W. powder	Emuls.	
1	15th July	0·01	314	530	0·1	271	445	332	491
2	31st Aug.	0·02	139	294	0·2	264	—	183	479
3	9th Sept.	0·01	304	492	0·1	126	343	350	450

Effect of insecticides on eggs and larvae.

Because they are sheltered by an overlying flap of outer cortical tissue, it is not possible to make contact with eggs and developing larvae with a normal field application of spray. Chemical control of these stages is therefore impossible unless the insecticide is capable of penetrating or by-passing the outer cortical tissues. On the BHC plots of the 1948 field trial, sprayed on 10th May, many unhatched eggs and dead young larvae were found under the split outer cortex of the canes within 2 to 3 weeks ; presumably these had been killed by some sort of " action-at-a-distance ". However, BHC killed no larvae on any of the canes used in the subsequent oviposition trials (described above) and it seemed, therefore, that its toxic powers were rather limited and were of value only on very young raspberry canes. DDT had no effect, even early in the year but parathion at 0·05 per cent. was very active and gave a complete kill of larvae whenever it was used.

Further trials were therefore initiated early in 1949 to examine the toxicity of BHC and parathion more closely. Insecticides and test canes were prepared as for the oviposition trials. As the canes were not slit until after the spray deposit had dried (see Fig. 1), any toxic effects must be due either to a local penetration of the outer cortical tissues or, possibly, to a diffusion of vapour through the mouth of the slit. Larval counts, taken about 3 weeks after spraying, are summarized in Table II.

TABLE II.

Numbers of T. theobaldi *larvae surviving on raspberry canes treated with insecticide.*

Trial no.	Date of application (1949)	Gamma BHC (%)						Parathion (%)				Control
		Emulsion				W. powder		Emulsion				
		0·02	0·01	0·005	0·0025	0·02	0·01	0·02	0·01	0·005	0·0025	
1	25th May	**53**	**111**	**198**	**283**	**168**	**273**	**0**	**12**	**5**	**110**	**284**
2	31st May	**10**	**31**	**31**	**94**	—	**33**	**0**	**0**	**6**	**3**	**90**
3	16th July	—	—	—	—	—	—	**0**	**0**	**0**	—	**389**

Figures differing significantly from the control at the 5 per cent. level are shown in heavy type.

Parathion, at concentrations of 0·005 per cent. and above, proved highly toxic in all tests and was significantly better than all other treatments except BHC emulsion at 0·02 per cent. in Trial 1. Trials 1 and 2 confirmed that BHC was effective against larvae when applied in May and again showed that the emulsion formulation was superior to the wettable powder.

The above results refer only to freshly applied insecticides. Other trials have indicated that the effective field life of parathion may be rather short. No accurate figures of total life are available but in some cases a significant decline in larvicidal activity has been apparent within two days of application.

Conclusions.

The insectary trials led to the following conclusions :

(1) Prior spraying of raspberry canes with either BHC, DDT or parathion gave no appreciable protection against oviposition by active midges.

(2) Throughout the spring and summer, parathion at concentrations of 0·005 per cent. and above was very toxic to eggs and larvae already present on the cane. BHC was moderately toxic in the spring only and DDT not appreciably toxic at any time of year.

(3) Emulsion formulations were slightly more effective than wettable powders.

FIELD TRIALS.

Two types of field trial were undertaken :

A. Soil treatments, aimed at the overwintering stages.

B. Sprays applied to the young canes, aimed either at ovipositing midges or at eggs and developing larvae. These sprays often had important secondary effects because of the large amount of insecticide falling on the soil around the base of the canes.

Method of recording.

Whenever possible the results of the field trials were assessed by three separate counts of the percentage of damaged canes. Usually 30 canes were chosen at random from each row sampled, giving a total of 150 canes per plot. The first count recorded the attack of Generation 1 of the midge and the second that of Generation 2. The third was taken in the following spring and recorded the canes killed by subsequent fungal attack. In counts 1 and 2, a category figure, based on the amount of damaged plant tissue, was assigned to each cane. These categories, ranging from 0–5, gave a better estimate of the predisposition to fungal attack than the simpler figure of percentage attacked canes and showed that, as well as reducing the number of canes attacked, a successful control measure usually cut the average amount of damage per attacked cane to about 60 per cent. of that on the controls. For the sake of clarity these figures have not been tabulated, except for a typical example in count 2, Table V.

Soil treatments.

Normally the midge spends the winter as a fully fed resting larva in a cocoon about 1 cm. below the surface of the soil, changing to a pupa during April and emerging as an adult in May. Throughout most of this period the cane is dormant and can

withstand materials which could not be used against the corresponding stages of the summer generations.

Tar oil, which Bennett and Kearns (1946) found effective against Pear Midge, and naphthalene were tested on large unreplicated plots on a one-acre field of the variety Newburgh. On 26th November, 1946, tar oil was applied at about 900 galls./acre at concentrations of 4 and 8 per cent. and crude naphthalene at 5·4 and 10·8 cwt./acre. Similar applications of tar oil were made to other plots on 10th April, 1947. The spring treatments of tar oil gave some control of the first midge generation; but this was probably an indirect effect, as the spray affected the vigour and splitting of the young canes and so reduced the number of available oviposition sites. No treatment controlled the second midge generation, but all slightly reduced the percentage of cane dying in the following spring.

Spray trials.

Because of the multivoltine annual cycle of the midge it is clearly best to attack the first and smallest generation. Usually this generation emerges over a period of 3 to 4 weeks, beginning in early May; but seasonal, climatic and topographical conditions can cause considerable variations from year to year and from place to place. Midges pair and begin oviposition within an hour or two of emergence, commonly laying 80 per cent. of their eggs in the first 24 hours of life. The ideal insecticide should therefore be both quick acting and persistent, a combination rarely found in practice.

Timing. For reasons of economy it is undesirable to apply more than two sprays in a season. With this and the above facts in mind, one of the following two timing policies could be adopted.

With substances such as BHC or DDT, which are expected to inhibit oviposition or to affect newly-emerged midges, the applications should ideally precede first and peak emergence, respectively, by the smallest possible margin. In practice this proved to be difficult, as emergence is unpredictable and largely dependent on day-to-day variations in the weather. In the later trials, therefore, the first application was not made until midges began to emerge or eggs were first found on the field in question ; the second application (if made) followed after an interval of about 14 days.

Substances such as parathion, with a mainly ovicidal or larvicidal action, should theoretically be applied to the canes between the arrival of the last eggs and the departure of the first larvae but this timing, too, is difficult in practice. Usually, therefore, the compromise described in the paragraph above was adopted, the first application being omitted if desired.

Only the broad outlines of timing are given in the text, the details being shown graphically in Fig. 2 so that a rapid comparison can be made of all the springtime field applications and the corresponding dates of midge emergence.

Trial 1, 1947. In this experiment DDT sprays were used against the active midges prior to or in the early stages of oviposition. Two applications were timed to precede first and peak midge emergence respectively, as described above. Initially half the plots received only the first application, but when the first count of attacked canes was made it became clear that neither treatment had given adequate control. A further application (No. 3), timed to control the second generation, was therefore made to the plots which had so far received only the first application.

This was done on 20th June; oviposition of the second generation began on 26th June, reaching a peak on 6th July.

About one acre of the variety Newburgh, at Lingfield, was divided into nine plots, one plot was left as an unsprayed control and the others arranged in four blocks of two. A commercial wettable powder formulation containing 20 per cent. w/w DDT (80 per cent. p.p'-isomer) was used at a dilution of 0·1 per cent. crude active ingredient. Applications 1, 2 and 3 used 181, 196 and 154 galls./acre of wash respectively. There was no significant difference between treatments and neither gave adequate control of the second midge generation, although both reduced the amount of dead cane as compared with the control plot. An unusually late and

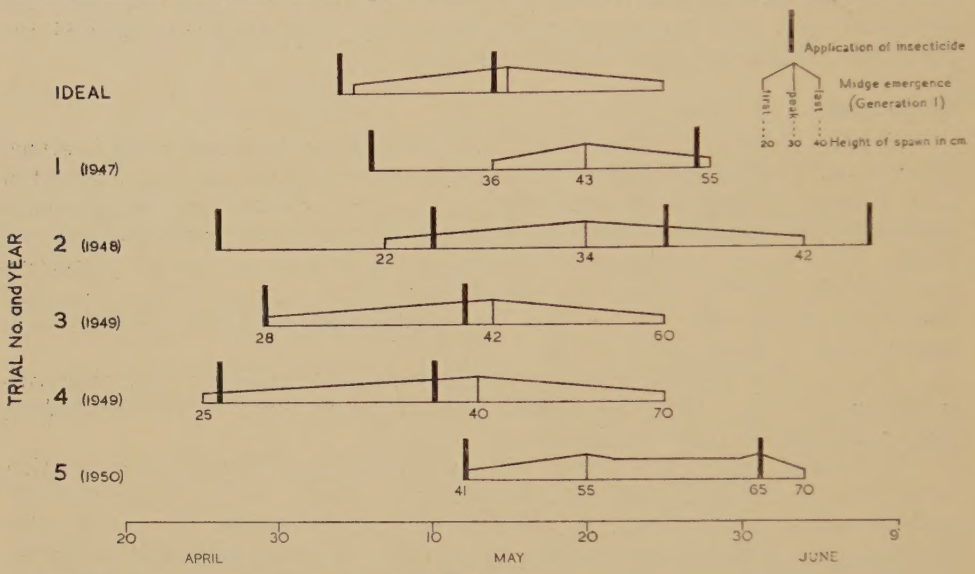

FIG. 2.

Timing of insecticide applications relative to midge emergence and raspberry cane growth.

short emergence period (see Fig. 2) may have contributed to this poor result but timing errors of this order are not uncommon in the field and it is clear that DDT, applied as in this trial, is not toxic enough to overcome them. This conclusion is in full agreement with the findings of the 1948 oviposition trials already described.

Trial 2, 1948. This trial was principally a straightforward comparison of the two insecticides BHC and DDT. In view of the results of Trial 1, all plots received two applications of spray and the soil around the base of the canes was wetted so that the midges would contact an appreciable amount of insecticide during their post-emergence drying-off period.

Twelve plots, each approximately 425 sq. yds. in area, were laid out on the field which was used in Trial 1.

An untreated plot, guarded by a buffer plot, was placed in the north-east corner and five blocks, each of two plots, arranged on the remainder.

Both insecticides were formulated as wettable powders and used at a concentration of 0·1 per cent. crude active ingredient (equivalent to 0·013 per cent. gamma

isomer in the case of BHC). A special formulation of BHC with inert constituents identical with those of the DDT was used for application 2 but was not ready in time for application 1, for which a 50 per cent. commercial preparation, based on goulac, was used. The timing plan resembled that of Trial 1 but the interval between applications was reduced as shown in Fig. 2. Applications 1 and 2 used 355 and 380 galls./acre respectively. The results of the cane counts are shown in Table III ; count 3 was based on a sample of 200 canes per plot.

TABLE III.

Spray Trial 2, 1948. Percentage of damaged canes following field applications of insecticides.

Count no. and date	DDT 0·1%	BHC 0·1%	Control
1 23rd-25th June ..	3·3	1·6	16·7
2 9th-11th August ..	16·2	5·3	50·0
3 21st April, 1949 (Dead canes) ..	2·8	2·0	13·0

Both treatments controlled the midge satisfactorily and gave a substantial reduction in the amount of dead cane. BHC was the better of the two at all counts, the difference being significant at the 5 per cent. level in count 2. It is probable that climatic differences, better timing and the spraying of the soil all contributed to the improved performance of DDT as compared with Trial 1.

Some indication of the relative efficiency of sprays and dusts was obtained from an unreplicated experiment carried out on another part of the same field. Five per cent. dusts of BHC and DDT, on a china clay base, were used and four applications were made, two at the same time as the sprays and two so arranged that they would form a toxic layer into which the fully fed larvae would fall on leaving the canes (see Fig. 2). Dust was applied, only to the rows, at a rate of about 90 lb./acre. The two early applications controlled the midge nearly as well as the corresponding sprays, but the later applications, especially of DDT, were markedly inferior.

Trial 3, 1949. This experiment sought to discover the *modus operandi* of the control achieved by the double spray of BHC on canes and soil in Trial 2. By comparing applications to canes and soil with carefully directed applications to the canes alone, it was hoped to decide whether it was the heavy soil application, acting against the newly-emerged midges, or the lighter deposit on the canes, with its mainly ovicidal and larvicidal action, which was the vital factor under field conditions.

A one-acre experimental plot of two varieties, situated at East Malling, was used. It was planted early in 1946 in six blocks, five of 800 sq. yds., one of which, the untreated control, was separated from the remainder by the sixth, smaller, buffer block ; the alleys between treated blocks were 5 yds. wide. The southern half of each block was of the resistant variety Malling Landmark and the northern of the susceptible Malling Enterprise ; both varieties were also divided into east and west halves which were given separate treatments with a BHC wettable powder identical

with that used in application 2 of Trial 2. Both treatments comprised two applications, those to canes and soil averaging about 310 galls./acre and those to canes only 25 galls./acre. The first application was made as soon as egg-laying began, the second following 14 days later. The results of two cane counts based on samples of 200 canes of Enterprise per plot are given in Table IV. Crop weights of both varieties were taken in 1950 instead of a dead cane count.

TABLE IV.

Spray Trial 3, 1949. Results of field applications of 0·1 per cent. BHC.

Count no. and date	Application to canes only	Application to canes and soil	Control
	Percentage attacked canes, 1949 (Enterprise)		
1 1st July	4·0	3·1	56·8
2 26th August	44·3	28·4	91·5
Variety	*Crop weights 1950 in lb. per 4 rows ≡ 100 sq. yds.*		
Enterprise	103·2	99·6	39·0
Landmark	211·5	215·6	213·6

Both treatments gave good control of the midge and more than doubled the crop on the susceptible variety Enterprise. The application to canes and soil appeared to be rather more efficient than that to canes only, but this difference was never significant at the 5 per cent. level. It thus appears that the control obtained with BHC is largely due to the deposit on the canes. In normal practice a considerable amount of wash will inevitably fall on the soil in the course of spraying the canes, but any additional wetting of the soil is clearly unnecessary.

Trial 4, 1949. Double applications of two toxicants, BHC and parathion, were compared in this trial. Two formulations of BHC were used, a wettable powder being compared with an emulsion of the type which had proved slightly more efficient in the insectary trials.

An old cane nursery of the variety Malling Promise, situated at East Malling, was modified for use in this experiment. The original broad swathes of cane were thinned to approximate to fruiting rows and subdivided into 21 plots, each 10 yds. square, separated by alleys 5 yds. wide. This allowed three replicate control plots to be randomized amongst the six replicates of each spray treatment without undue risk of dispersal of midges. The BHC wettable powder was identical with that used in application 2 of Trial 2 ; the emulsion was a commercial preparation containing 3 per cent. w/w gamma BHC dissolved in diacetone alcohol and with an anionic emulsifying agent of the sulphonated fatty ester type. After dilution to the required concentration, dioctyl sodium sulphosuccinate at 0·0125 per cent. was added to ensure satisfactory wetting of the canes. Both BHC preparations were used at a concentration of 0·013 per cent. gamma isomer in the diluted wash. The parathion

was prepared according to the following formula, expressed as a percentage of the diluted wash:

Commercial parathion (75 per cent. active ingredient) ..	0·025 per cent.
Anhydrous *cyclo* hexylamine dodecyl sulphate	0·0125 ,, ,,
Diacetone alcohol	0·25 ,, ,,
Dioctyl sodium sulphosuccinate	0·0125 ,, ,,

As soon as the first eggs were found, all treated plots received an application of the appropriate material, followed 14 days later by a second. All sprays were applied to both canes and soil, using approximately 300 galls./acre of the emulsions and 270 galls./acre of the wettable powder at each application. The results of cane counts are given in Table V.

TABLE V.

Spray Trial 4, 1949. Percentage of damaged canes following field applications of insecticides.

Count no. and date	Gamma BHC 0·013%		Parathion 0·025 %	Control
	Wettable powder	Emulsion		
1 22nd-23rd June	0·67	0·33	0·22	17·6
2 16th-17th August	18·6 (1·46)	27·1 (1·40)	33·2 (1·38)	57·1 (2·26)
3 14th April, 1950 (Dead canes)	1·1	1·7	2·5	4·4

At the 5 per cent. level there were no significant differences between treatments in count 1, although all were better than the control. In count 2, BHC wettable powder was significantly better than the other treatments which did not differ between themselves, although both were superior to the control. In addition the average category figure per attacked cane (given in brackets) was significantly higher on the control plot than on the treated plots considered together. The amount of dead cane was significantly reduced by both BHC treatments but not by parathion. The superiority of the wettable powder formulation of BHC over the emulsion is substantially a reversal of the findings of the insectary trials and may be a reflection of the fact that, under field conditions, the effective life of a spray deposit is often of more importance than its immediate toxicity.

Trial 5, 1950. This final trial sought to discover whether reducing the number of applications from two to one would cause any serious loss of control. In addition, a further comparison was made of BHC as a wettable powder and parathion as an emulsion but at a lower concentration than in Trial 4.

Four blocks, each of five plots, were arranged on the site used in Trial 4, leaving one surplus plot. Each block consisted of one plot of each treatment and an untreated control. The plots were randomized without regard to the previous years' treatments. Both insecticides were commercial formulations, the BHC being a

50 per cent. preparation, as used in application 1 of Trial 2, and the parathion containing 20 per cent. w/w active ingredient dissolved in diacetone alcohol, together with a non-ionic emulsifying agent of the ethylene oxide condensate type. BHC and parathion were used at 0·1 per cent. and 0·01 per cent. crude active ingredient, respectively. Dioctyl sodium sulphosuccinate at 0·0125 per cent. of the dilute wash was added to both materials as a subsidiary wetter. The timing of the double sprays was identical for both materials but, in order to make the best use of their differing properties, that of the single sprays was not. The more persistent BHC was included in the first application to cover early and peak midge emergence and the shorter-lived but more active parathion delayed until the second, when there was an accumulation of eggs and larvae on the canes. In view of the results of Trial 3 no special attempt was made to wet the soil, although spray fell freely on it during the course of a thorough wetting of the canes. Because of the heavy growth of spawn the amount of spray applied was abnormally high, averaging 550 and 710 galls./acre at the first and second applications respectively. The additional wetter greatly improved the covering power of the wettable powder. The results of the two summer cane counts are given in Table VI. Soon after count 2 the plot was grubbed, so no dead cane count was possible.

TABLE VI.

Spray Trial 5, 1950. Percentage of damaged canes following field application of insecticides.

Count no. and date	BHC 0·1%		Parathion 0·01%		Control
	No. of applications				
	1	2	1	2	
1 3rd-5th July	1·5	0·17	0·33	0	23·3
2 8th-12th August ..	9·5	3·5	6·2	5·0	69·3

All treatments gave an efficient control of the midge, significant at the 5 per cent. level in both counts. None of the differences between treatments were significant; but it would perhaps be rash to assume from this one result, obtained in a somewhat unusual season, that all four treatments would always prove equally efficient.

DISCUSSION.

Naphthalene and tar oil applied to the soil during cane dormancy failed to give adequate control.

Fig. 2 shows that both the initiation and the duration of midge emergence may vary considerably from year to year and from place to place. Timing of sprays can therefore be only loosely coupled with date and with height of canes and in Trials 1 and 2, where attempts were made to predict the date of first emergence,

treatments were applied considerably in advance of the optimum dates. In subsequent trials the timing, based on local biological observations, was satisfactory, although the absence of a clear emergence peak in 1950 gave difficulties with application 2.

The experience of several years suggests that, whatever the insecticide, the degree of midge control is to some extent dependent on the weather, best results being achieved in the cool summers of 1948 and 1950. Of the three materials tested, BHC was the most successful, probably because it was the only one combining ovicidal and larvicidal properties with an appreciable and lasting toxicity to the emerging midges. Both the insectary trials and Spray Trial 3 suggest that the former properties are the most important, although Trial 3 also offers evidence that the spray falling on the soil contributes something to the total effect of a normal field application. In this connection it is noteworthy that Bachmann (1950) was able to show that emerging midges were quickly paralysed by a deposit of BHC on the soil. Two applications of wettable powder, the common element in Trials 2–5, were consistently satisfactory, being equal to or better than any other treatment. In Trial 5, one application was not appreciably inferior to two, although in a warmer season the difference might have been more pronounced. In the field the emulsion formulation used in Trial 4 failed to show the superiority over the wettable powder which had been evident in the insectary trials. This, coupled with its higher cost, caused it to be omitted from subsequent field trials.

Parathion, even at an abnormally high concentration (Trial 4), was no better than BHC in the field. It seems probable that the disadvantages of its shorter effective life outweighed the advantages of its greater toxicity to eggs and larvae. The latter property is valuable if spraying has been delayed until well after the start of egg-laying, but in all normal cases BHC is to be preferred because of its greater reliability and its lower mammalian toxicity.

DDT, which is not toxic to eggs or larvae, was markedly inferior to BHC. In Trial 2, improved timing and a heavy soil application combined with a cool season gave better results than in Trial 1 and an economic degree of control was achieved. At best, however, it is a poor alternative to BHC, being more costly and less efficient.

Dusts of BHC and DDT were slightly less effective than the corresponding wettable powder sprays, but would be useful in circumstances where spraying is impossible. It is concluded that a double application of BHC wettable powder at a concentration of 0·1 per cent. of the crude active ingredient is the most efficient midge control measure for field use. Details of application techniques and timing have already been published in a growers' bulletin (Pitcher, 1951).

Satisfactory midge control will always greatly reduce the available avenues of infection for the fungi which cause the disease Midge Blight; but the extent to which this is reflected in terms of a reduced cane death-rate or an increased yield depends largely on the raspberry variety concerned. Some, such as Newburgh and Malling Enterprise (Trials 1, 2 and 3), which are very susceptible to both midge and blight, show a conspicuous improvement, while others, such as Malling Promise (Trial 4), which are midge susceptible but comparatively blight resistant, show less benefit from an efficient insecticide. Midge resistant varieties, such as Malling Landmark (Trial 3), naturally show little or no benefit from midge control measures.

SUMMARY.

Trials on the control of the Raspberry Cane Midge (*Thomasiniana theobaldi* Barnes) carried out in the years 1947-50 inclusive lead to the following conclusions :

In laboratory and insectary trials DDT, BHC and parathion, in the form of a spray deposit on the canes, did not prevent active midges from laying large numbers of eggs. Throughout the spring and summer parathion at 0·05 to 0·005 per cent. gave a very high kill of eggs and larvae by means of a local penetration of the outer cortical tissues of the cane. BHC at 0·02 to 0·005 per cent. gamma isomer showed this effect in a lesser degree in May-June only. DDT showed no such effect.

In field trials, soil treatments of 4 and 8 per cent. tar oil at about 900 galls./acre and naphthalene at 5·4 and 10·8 cwt./acre failed to give adequate control. DDT wettable powder at 0·1 per cent. was effective only if the soil also was sprayed. Two applications of BHC at 0·1 per cent. crude active ingredient in a wettable powder formulation gave good results in all four trials in which it was used and can be recommended as an efficient control measure. In one trial this treatment did not differ significantly from one application of wettable powder but, in another, it was superior to two applications of a BHC emulsion of the same strength. Five per cent. dusts of BHC and DDT were slightly less effective than wettable powders. Parathion gave variable results, once (at 0·01 per cent.) equalling BHC wettable powder and once (at 0·025 per cent.) being inferior.

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THE INFLUENCE OF ORCHARD NUTRITION UPON THE ACIDITY RELATIONSHIPS IN CORTLAND APPLES

By C. A. EAVES and J. S. LEEFE

Dominion Experimental Station, Kentville, Nova Scotia

MANY different approaches to the study of storage quality of apples have been made with the emphasis largely placed on post-harvest physiology. This has been due to the great variability encountered in individual tree performance (Hoblyn, 9) which, in turn, may be due to inherent differences in rootstock and scion or be a result of climate, soil, disease or insect pests. This variability is shown even between different parts of the tree where, as Martin (12) has noted, each branch may behave as an organic unit.

The thorough investigations of Haynes and Archbold (6, 7) in England of the physiology of apples were based on the analysis of fruit from commercial orchards, and then related to subsequent biochemical changes in storage. They suggested that acid metabolism is correlated with the sugar metabolism of the apple and that nitrogen is a measure of the protoplasmic content which in turn governs the rate of respiration. Pearson and Robertson (13) likewise concluded that the organic acids form the connecting link between the respiration mechanism and protein synthesis in the apple. Krotkov (11), on the other hand, related the respiration of McIntosh apples to the content of insoluble phosphorus, and referred to it as the " protoplasmic factor ". Davis and Blair (3) likewise stressed the importance of the P/N ratio in respect of keeping quality. Wallace (15) pointed out the need for adequate supplies of potassium in relation to nitrogen and this has more recently been confirmed by Hill *et al.* (8). The respiration of McIntosh apples at 74° F. from trees receiving three levels of nitrogen was associated with the nitrogen in the foliage by Boynton *et al.* (2). It thus seems generally agreed that while the acid content of the fruit is a critical factor in determining storage behaviour, this in turn is closely related to the nutrient uptake of the apple tree. The present report, as a part of a broad investigation into the storage quality of Cortland apples, deals specifically with data obtained in 1952, based on preliminary observations shown in Figs. 1 and 2.

MATERIALS AND METHODS.

The fruit used in the investigation was harvested from an experimental orchard of Cortland apple trees already described in detail (4). The orchard is divided into four main blocks, namely :

A No treatment ;
B Dolomitic limestone, 2 tons/acre, 1945 and 1950 ;
C Dolomitic limestone, 2 tons/acre, plus superphosphate, 1,000 lb./acre, 1945 and 1950 ;
D Superphosphate, 1,000 lb./acre, 1945 and 1950.

There are fifteen annual treatments superimposed across the blocks using various combinations of ammonium nitrate, superphosphate and muriate of potash. Because of physical limitations only ten plots in each block were used for acidity determinations. These are shown in Table III.

A random sample of 100 fruits was removed from each of three trees in the plots on three harvesting dates four days apart. After acidity determinations had been made, twenty-five apples were stored at 65° F. for one week and the remainder at 34° F. for five months, after which time they were kept at 65° F. for one week prior to analysis. As the investigation necessitated observations of factors other than acidity on the 120 samples at each picking date, it was found necessary to devise a rapid technique for juice extraction. This was accomplished by collecting drops of juice from the cut surface of the apple when hardness measurements were being made with the pressure tester. Pressure readings from the blushed side of ten apples provided the required 2 ml. juice, which was diluted to 10 ml. before titration with 0·1 N $Ba(OH)_2$ in order to determine the acidity, using phenolphthalein as the indicator. No significant differences were found in a trial of this rapid method of extraction against that used in previous years when the halves of ten apples were macerated and the juice was expressed through a double layer of cheesecloth. This rapid technique is being further investigated as a possible field test for fruit maturity, based on acidity. Acid content is expressed in the text as percentage of malic acid, based on fresh weight.

The observations on foliage analysis, except those made in 1952, are based on data previously reported (Eaves and Kelsall, 4) and no changes were made in the sampling or analytical procedures.

Results.

Acid Content.

The effect on acid content of maturity, liming and fertilizer treatments and levels of nutrients in the foliage was examined.

Effect of Maturity. The average acid contents of the fruit from all plots at three dates of picking are shown in Table I where the indication is that fruit at the third

Table I.

Acid content of Cortland apples at three different harvest dates.

Picking	Malic acid content as percentage
1st	0·726
2nd	0·726
3rd	0·683
Significant difference P=0·05	0·028

date of picking had a significantly lower acid content than had that from the first two pickings.

Effect of dolomitic limestone and of superphosphate. In Table II it will be seen that dolomitic limestone had a depressing influence on acid content ; this effect has been

consistently observed in past seasons. No effects were observed from the application of superphosphate.

TABLE II.

Influence of dolomitic limestone on the acid content of Cortland apples (percentage of malic acid) at harvest and after storage at 65° F. (1 week).

	At harvest	1 week at 65° F.
Without lime	0·739	0·682
With lime	0·683	0·638
Significant difference P=0·05	0·016	0·021

Effect of annual fertilizer treatments. The influence of the annual treatments on acid content is shown in Table III. Apples from the plot receiving potash alone had a significantly higher acid content than had those from the untreated plots and the plots receiving nitrogen alone. In addition, fruit from trees treated with a complete fertilizer had a significantly higher acid content than had that from the untreated trees.

TABLE III.

Influence of applied nitrogen, phosphorus and potassium on the acid content of Cortland apples (percentage of malic acid).

Treatment* 1,000 lb. mixtures per acre N P K	Acid content (average of 4 plots)	
	At harvest	1 week at 65° F.
0 – 0 – 0	0·67	0·64
0 – 10 – 0	0·72	0·67
0 – 0 – 5	0·76	0·70
0 – 10 – 5	0·71	0·60
3 – 0 – 0	0·66	0·61
9 – 0 – 0	0·68	0·62
16 – 0 – 0	0·71	0·66
3 – 10 – 5	0·76	0·68
9 – 10 – 5	0·72	0·68
16 – 10 – 5	0·74	0·71
Significant difference P=0·05	0·05	0·04

* N = Percentage N, supplied as ammonium nitrate, 33% N
P = Percentage P_2O_5, supplied as superphosphate, 20% P_2O_5
K = Percentage K_2O, supplied as muriate of potash, 60% K_2O

The partial regression coefficients of acid content at all picking dates on the N, P and K content of the leaves were calculated. The only two statistically significant relationships found were between K and acid content at the first and

second picking dates. The associated correlation coefficients were + 0·666 (P=0·05) and + 0·386 (P=0·01). A study of the acid content in relation to the lime-phosphorus treatments led to a reconsideration of the phosphorus levels in the leaves and it was found that additions of lime to plots without nitrogen, particularly those receiving phosphorus alone, caused a very marked reduction in P levels. This effect was much less marked in the potash plots and negligible in the N treated plots. Table IV illustrates this effect together with corresponding reductions in acid content.

Table IV.

Reductions in acid content (percentage of malic acid) and in leaf phosphorus, due to applications of dolomitic limestone to Cortland apple trees.

Annual treatments	1950		1951		1952	
	Acid	Total P p.p.m.	Acid	Total P p.p.m.	Acid	Total P p.p.m.
P only	0·141	425	0·147	530	0·160	450
K only ..	0·013	200	0·067	360	0·087	120
N only ..	0·020	95	0·020	90	0·026	90

Acid Loss.

Effect of maturity. There was no significant difference between the amount of acid lost from apples picked on different dates.

Effect of dolomitic limestone and of phosphorus. Unlike their effect on acid content, additions of lime did not appear to influence acid loss and the only significant block treatment effect was the relatively high acid loss shown by fruit from the super-phosphate treatment at the first picking (see Table V).

Table V.

Influence of dolomitic limestone and superphosphate on acid loss in Cortland apples (percentage of total malic acid content) picked at three dates of harvest, after storage at 34° F. for 5 months and for 1 week at 65° F.

Block treatment*	First picking	Second picking	Third picking
No treatment	54·01	57·64	57·27
Lime	55·93	56·48	58·14
Lime and Superphosphate	58·69	56·51	60·20
Superphosphate	59·62	55·96	58·60
Significant difference P=0·05	3·30	5·30	4·00

* Dolomitic limestone, 2 tons per acre, 1945 and 1950.
Superphosphate, 1,000 lb. per acre, 1945 and 1950.

Effect of annual fertilizer treatments. It will be seen from Table VI that the fruit from the untreated trees showed a significantly lower acid loss than did apples from the N only treatments at all pickings, save from 9N at the first picking, and

from the P treatments at the first two pickings. The fruit from the K only-treated trees also showed a significantly lower acid loss than did that from the N treatments at the third picking. Moreover, at the last two dates of picking, the apples from the trees treated with N only lost a significantly higher percentage of acid than did those from the NPK plots, thus pointing to a decelerating influence of potassium on acid loss.

The mean values for acid loss for all pickings further accentuate the differences noted above.

TABLE VI.

Influence of applied nitrogen, phosphorus and potassium on the acid loss in Cortland apples (percentage of total malic acid content) after storage at 34° F. for 5 months and for 1 week at 65° F.

Annual treatment	First picking	Second picking	Third picking	Mean
O	51·95	49·23	55·37	52·18
P	58·45	59·70	57·74	58·66
K	53·13	56·46	55·24	54·94
PK	57·54	55·81	57·90	57·08
3N	59·57	61·61	60·57	60·58
9N	56·91	59·10	64·53	60·18
16N	59·69	60·18	62·28	60·72
3NPK	56·47	53·45	54·24	54·72
9NPK	61·20	54·07	57·34	57·54
16NPK	55·71	54·83	57·42	56·00
Significant difference P=0·05 ..	5·22	5·30	4·00	2·61

Correlation coefficients for N/K, K, N and P in the leaves with acid loss are shown in Table VII.

TABLE VII.

Nitrogen, phosphorus and potassium contents of Cortland apple leaves in relation to acid loss in the fruit stored at 34° F. for 5 months and for 1 week at 65° F. (correlation coefficients).

Picking	N/K acid loss	K acid loss	N acid loss	P acid loss
1st	+0·274	−0·267	−0·196	+0·519
2nd	+0·356	−0·240	−0·049	+0·073
3rd	+0·573	−0·545	+0·324	+0·154

Significant correlation coefficient at 5% level ±0·325

The correlation coefficients in Table VI show that acid loss and the N/K ratio are positively associated, but with K alone the relationship is negative. The positive relationship between P and acid loss is significant only at the first date of picking ; it is of interest, however, to note that both the block and annual treatments of applied P were also associated with a high rate of acid loss at the first date of picking.

Soil moisture supply is an important factor in nutrient uptake and profoundly affects the number of ions that are leached out or made available in any given soil. It has been noted previously (4) that, under the conditions of this experiment, P and K were more readily utilized under moist conditions but that magnesium was subject to leaching. Clearly, then, if the availability of these elements varies in terms of nutrient levels in the leaves over a wider range than that induced by their liberal application in the form of fertilizer, any subsequent physiological observations on the fruit are of restricted value without some kind of nutrient calibration. Reference to Fig. 1 illustrates this point.

Table VIII.

Seasonal precipitation in relation to leaf nutrient levels and the acidity of Cortland apples.

Year	Rainfall (inches) April, May, June	Acid content at harvest	Acid loss % 5 months 34° F.	Per cent. dry matter					
				N	K	N/K	P	Mg	Ca
1950	4·50	0·63	52·9	2·03	1·47	1·40	0·154	0·234	1·42
1951	8·20	0·65	54·2	1·91	1·80	1·06	0·187	0·149	1·38
1952*	6·30	0·68	58·0	2·40	2·08	1·15	0·254	0·218	1·19

* Winter of 1952 record snowfall, 154 in.
(1950 = 100 in., 1951 = 68 in.)

The period April to June inclusive referred to in Table VII is approximately the time between the initiation of terminal growth and date of sampling of the leaves, which was undertaken during the first or second week in July.

The figures of greatest interest in the above Table are those for 1952, which show relatively high levels of N, P, K and Mg, also of acid content and loss of acid.

No explanation can be offered to account for these high levels, except that they are associated with 154 in. of snowfall (38-year average, 80 in.) in the preceding winter.

The year 1950 was characterized by low spring rainfall prior to sampling and it will be seen that relatively low levels of acid and acid loss were associated with low levels of N, P, K and high Mg in the leaves. The acid content and loss in storage are positively associated each year, and the N/K ratio is lowest in years with the highest rainfall in the spring. It should be noted that the subsequent rainfall in July, August and September during the years under study was much the same, and that it is quite possible that seasonal conditions between leaf sampling and fruit harvest could markedly change the acid relationships that have been found in this investigation.

DISCUSSION.

It has been shown that from year to year a low acid content at harvest in Cortland apples is followed by a low acid loss in storage which is in agreement with the observations of Plagge and Gerhardt (14).

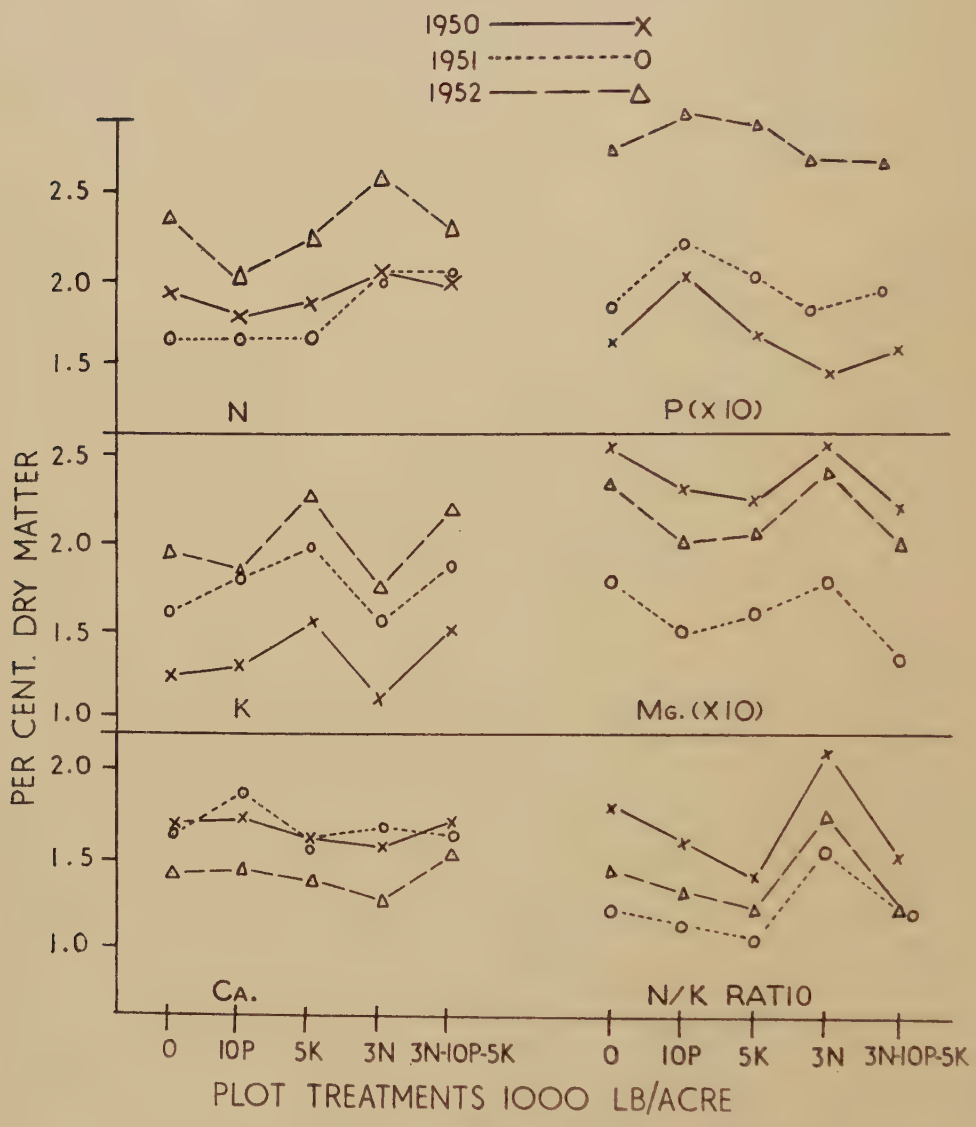

Fig. 1.

Influence of Nitrogen, Phosphorus, and Potassium on the chemical composition of Cortland apple leaves 1950-52.

No significant relationship was found between acid content and the nitrogen applied as fertilizer or as nitrogen found in the foliage. Gourley and Hopkins (5), working with controlled levels of applied nitrogen, and Haynes and Archbold (7), who studied the nitrogen relationships in fruit from commercial orchards, also failed to establish clear-cut evidence of such a relationship. The latter workers related nitrogen content of the apple to the size and crop and also to acid loss. In the

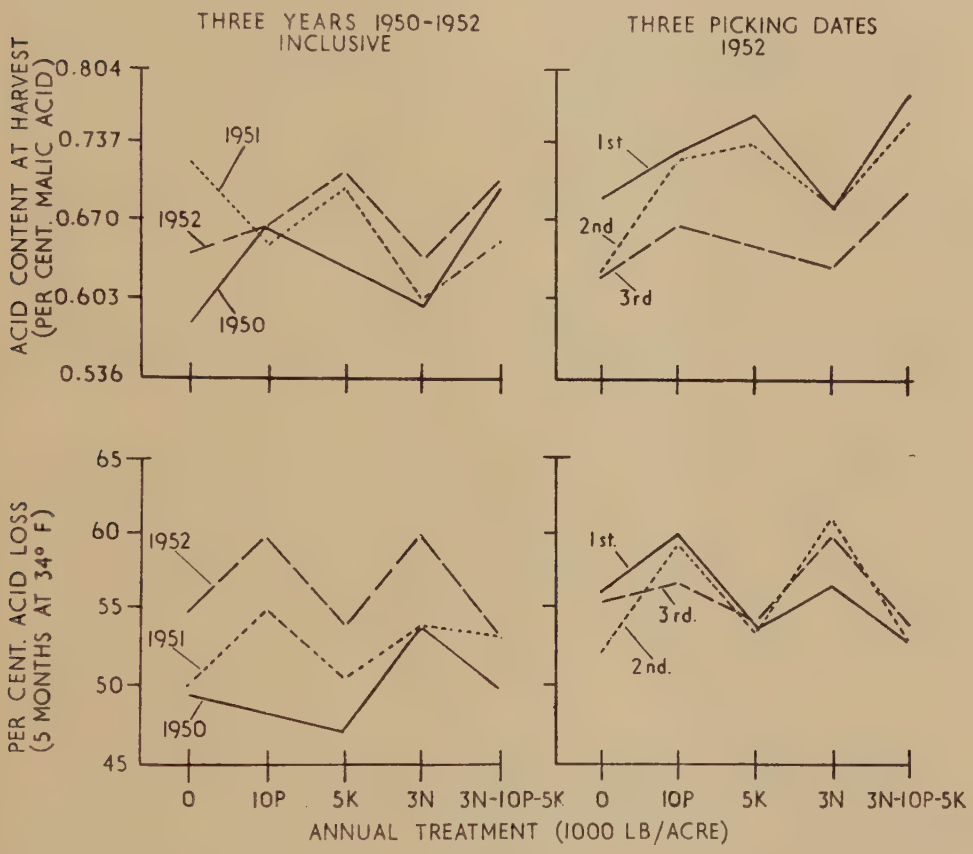

Fig. 2.

Acidity relationships in Cortland apples as influenced by nutritional treatment.

present investigation, whilst no direct correlation between foliage N and acid loss was established, there was a significantly greater loss in fruit from nitrogen-treated trees than from untreated trees and those receiving potassium only. In contrast, it has been shown that leaf potassium is associated positively with acid content and negatively with acid loss ; the latter relationship reached the 5 per cent. level of significance at the last pick. Indeed, it is interesting to note the similarity between the graphs for leaf K and acid content (see Figs. 1 and 2) which suggest that K is the governing factor in acid formation. However, the N/K ratio, which was found

to be positively associated with acid loss, serves to underline the importance of the so-called dilution effect of applied nitrogen upon potassium content, which in turn profoundly affects the post-harvest metabolism of the fruit.

With regard to phosphorus, there is no significant relationship between this element and acid content ; nevertheless there appeared to be a close association between the reduction of leaf P and acid content in fruit from trees which had received dolomitic limestone. Leaf P and acid loss were positively associated and this may possibly account for the development of internal breakdown in apples which was associated with high levels of applied phosphorus in relation to N, as reported by Davis and Blair (3).

The use of dolomitic limestone has been shown to exert a depressing effect upon acid content and, while it was first concluded that this was due to a general reduction in the levels of potassium, indications noted above suggest that there is also an association with phosphorus levels. This problem is now being further investigated. Brown (1) showed that levels of calcium in the soil were reflected in the calcium content of the apple but did not indicate how this element affected keeping quality.

Kidd and West (10) concluded that titratable acidity of developing fruit varies widely with populations, localities and seasons. Similarly it has been shown in the present paper that nutrient levels and acidity relationships are affected by seasonal fluctuations, and it has been suggested that, on the plots receiving phosphorus and potassium, they may vary more with precipitation than with liberal applications of these elements applied as fertilizers.

From a practical standpoint, the fruit grower is always trying to improve production without impairing quality. Assuming, for the sake of discussion, that acid content is an index of metabolism and represents the major factor in quality, how do the foregoing observations assist in achieving the objective ?

Schematically the results are shown as follows :

	Acid content	*Acid loss*
No treatment	Low	Low
Plus N	Low-Medium	High
Plus P	Medium	High
Plus K	High	Low
Plus NPK	Medium	Medium

If it is further assumed that untreated trees produce fruit of good quality, then it is seen that, under the conditions of this experiment, they should have a low acid content and lose acid slowly in storage. However, in order to be productive, additional applied nitrogen is considered essential which, according to the schema, has no effect on the acid content but is associated with accelerated acid loss. The addition of potash will increase the acid content but will help to counteract the influence of nitrogen in the acid loss. These associations are an over-simplification of a series of complex reactions ; nevertheless, they suggest that understanding of the nutrient/acid relationship for individual apple varieties might aid in the problem of quantity *v.* quality.

In view of the seasonal fluctuations in the general uptake of minerals, it would seem desirable that cultural methods should be such that the optimum nutrient levels could be maintained from year to year. The results obtained above would indicate that a nutrient calibration of apple trees is also desirable as a basis for subsequent physiological studies of the fruit in storage.

SUMMARY.

A technique is described for the rapid estimation of titratable acidity in apples.

Cortland apples picked on three different dates were found to have significantly less acid at the last date but there was no difference in acid loss in storage at 34° F. for five months.

Acid content was positively correlated with potassium in the leaves; fruit from the trees receiving potassium had a significantly higher acid content than had apples from both the untreated and the nitrogen-treated plots. There was a significant reduction in acid content due to the application of dolomitic limestone.

Acid loss was positively correlated with the nitrogen/potassium ratio in the leaves. Fruit from both the nitrogen and phosphorus treated plots was significantly higher in acid loss than was that from the untreated and potash-treated trees. No association was found between liming treatments and acid loss.

Observations over a period of three years showed that acid content was positively associated with acid loss and that seasonal precipitation influenced these relationships.

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SOME FACTORS AFFECTING THE BALANCE OF PHYTOPHAGOUS AND PREDACIOUS MITES ON APPLE IN SOUTH-EAST ENGLAND

By ELSIE COLLYER and A. H. M. KIRBY
East Malling Research Station, Kent

A study of the importance of predators of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), in Nova Scotian orchards twenty years ago led Gilliatt (1935) to conclude that another mite, *Seiulus pomi* Parrott, predacious on *M. ulmi*, was a major factor in the control of the latter under suitable conditions. *S. pomi*, however, was found to be very susceptible to the winter oil and lime-sulphur sprays applied as a routine at that time, and was unable to prevent increases of *M. ulmi* in such orchards. Similar increases of *M. ulmi* in Ohio orchards receiving sulphur sprays were attributed by Cutright (1944) to the greater susceptibility of predacious mites to this chemical.

The study of the interaction of the spray programme with the balance between *M. ulmi* and its predators has received much attention in Nova Scotia during the last decade and attempts have been made to devise programmes which, by interfering as little as possible with important predators, would ultimately prove more efficient (Pickett *et al.*, 1946; Pickett and Patterson, 1953). It was found (Lord, 1949) that, contrary to the views expressed by Gilliatt (1935), Bordeaux mixture was harmless to all important predators of *M. ulmi*, but that new fungicides such as ferbam or 2 : 3-dichloro-1 : 4-naphthaquinone were as toxic as sulphur to some, including the important predacious mite, *Iphidulus tiliae* (Oudms.). The peak average density of *M. ulmi* on trees receiving flotation sulphur sprays was such as to produce severe bronzing and loss of crop in each of the seasons 1944 to 1948, whereas that on trees, in the same orchard, receiving Bordeaux and "fixed copper" sprays was always much lower and of no economic significance (Lord, 1949).

The value of predacious insects, notably the Black-kneed Capsid (*Blepharidopterus angulatus* (Fall.)), in reducing infestations of *M. ulmi* in south-east England was clearly shown in 1944 (Austin and Massee, 1947); since then many species have been found to feed on *M. ulmi* in this area, and mites of a number of species of *Typhlodromus* (= *Seius*, *Seiulus*, or *Iphidulus*: Nesbitt, 1951) and of allied genera of the family Laelaptidae have been shown to play an important role, especially in unsprayed orchards (Collyer, 1953a, b, c). Although the use of fungicides of low toxicity to these predators was desirable, the Canadian success with copper sprays could not be applied, as both Bordeaux mixture and colloidal copper had been shown to be extremely phytotoxic on dessert varieties and to be associated with a greater incidence of *M. ulmi* than was found on plots receiving lime-sulphur (Moore and Montgomery, 1937; Moore, 1938).

Progress in the study of the role of predacious mites in the control of *M. ulmi* on apple in south-east England therefore depended on the discovery of an effective fungicide, safe on dessert varieties and harmless to the mite predators. The first indications that such a chemical was available came with the reports of Chandler

and Thurston (1949) and Hilborn and Lathrop (1950) that a fungicide based on 2-heptadecylglyoxalidine had given satisfactory control of scab in eastern U.S.A. without the need for acaricides, which were required where sulphur, ferbam or 2 : 3-dichloro-1 : 4-naphthaquinone fungicides had been used. Two grades of this fungicide were found promising for scab control at East Malling in 1949 (Moore and Kirby, 1952), and a preliminary trial in Essex in 1950 showed them to have low toxicity towards all insects and mites present.

Sufficient progress had thus been made to justify an attempt to determine the influence of certain fungicide programmes upon the population levels of predators, especially mites of the genus *Typhlodromus*, in relation to the infestations of *M. ulmi* found upon the same trees year by year. As another organic fungicide, based on a substituted sulphenamide, had by this time been found effective against scab and safe on sulphur-shy varieties (Byrde and Marsh, 1951 ; Moore and Kirby, 1952), it was decided to include it as one of the treatments.

Experimental procedure.

Materials.

Four fungicide treatments were chosen, two based on inorganic sulphur and two on organic compounds (one, 341SC, containing no sulphur) ; the strengths used at green-cluster, pink-bud, petal-fall and fruitlet stages are shown below :

Lime-sulphur	3·0, 2·0, 1·0 and 0·75 per cent.
Dispersible sulphur	0·5, 0·5, 0·3 and 0·3 per cent.
2-Heptadecylglyoxalidine (341SC)	0·075 per cent. of active ingredient at each application.
N-Trichloromethylthio-tetrahydrophthalimide (SR406)	0·1 per cent. of active ingredient at each application.

The lime-sulphur was an " approved " commercial product ; the dispersible sulphur was also commercial and contained approximately 94 per cent. elemental sulphur. The 2-heptadecylglyoxalidine had been manufactured from commercially pure stearic acid and therefore contained very little of any homologue ; it was obtained as the acetate dissolved in *iso*propanol, and the active base was set free in the spray-tank by adding ½ lb. of slaked lime to 100 gallons of water containing 3 pints of 341SC. SR406 was a commercial wettable powder containing 50 per cent. of N-trichloromethylthiotetrahydrophthalimide.

Each year, nicotine, 0·05 per cent., was applied with the petal-fall applications for control of Apple Sawfly, and lead arsenate, 0·2 per cent., in late June for Codling Moth. No applications of winter washes were made during the three seasons covered by the experiment, although a routine tar-oil had been customary in previous years ; DDT (5 lb. of a 20 per cent. wettable powder per 100 gallons) was added to the green-cluster applications in 1951 only.

Applications were by lance at 300-350 lb. p.s.i. in each case. Difficulty was experienced in the green-cluster application of 341SC in the first year, as agitation in the tank was insufficient and much of the active material was left at the bottom of the tank ; this occurrence does not seem to have had any effect on the results of the trial, but this material was applied on all subsequent occasions from another machine with efficient agitation.

Layout.

The experiment was conducted on alternate rows of Cox's Orange Pippin and Worcester Pearmain on M.II stocks, nearly twenty years old, in a commercial orchard at Ryarsh, Kent. The trees had always been lightly pruned and were closely spaced. It was arranged in four randomized blocks each containing one plot of each of the four treatments. Each plot contained two recorded trees, one of each variety, and was guarded on all sides by at least one unrecorded tree.

FLUCTUATIONS IN THE DENSITIES OF *M. ulmi* POPULATIONS.

The degree of infestation by *M. ulmi* was estimated in 1951 and 1952 by the leaf-imprint method (Austin and Massee, 1947), taking 24 leaves from each recorded tree on each occasion ; in 1953, a mite-brushing machine (Henderson and McBurnie, 1943) was used with a sample of 25 leaves. A winter egg count was made late each autumn on five samples from each recorded tree, using 1 in. of wood surrounding the first clear bud on the basal portion of the current year's growth. For the purposes of this paper the data obtained for the two varieties have been combined.

The degree of infestation by *M. ulmi* associated with each treatment, as measured by the mean number of active mites plus summer eggs per leaf, is shown in Fig. 1. For convenience, a logarithmic vertical scale has been used, and the graphs should be studied in conjunction with Table I, which indicates the significance of the differences observed between treatments. It is not possible to interpret the densities of mites per leaf sample in terms of the total populations on the tree. During the early summer, increases in leaf area are so great that real increases in mite populations may be accompanied by apparent decreases as judged by mean leaf density.

The data shown in Tables I and III and illustrated in Figs. 1 and 2 are therefore the nett results of a number of biotic factors. The winter egg infestations are given in Table II ; total eggs represent red (intact) eggs plus eggs made translucent by predation.

At the commencement of the experiment in 1951, considerable populations of *M. ulmi* were present, leading to bronzing of the foliage in July. A category record showed least bronzing on the lime-sulphur plots ; considerable bronzing occurred on the other treatments, especially on Worcester Pearmain trees. This indicates that greater infestations followed the initial use of the organic fungicides or elemental sulphur than followed the use of lime-sulphur which is known to be acaricidal *per se*. By September, however, trees receiving lime-sulphur carried significantly larger populations than those receiving SR406 ; those on trees receiving the other treatments were intermediate. This order of infestation was reflected in the winter-egg densities and in the first count in 1952. Thereafter all populations fell abruptly during the early summer and significant differences only emerged later ; these were again reflected in the winter egg densities and in the May, 1953, counts. In 1953, summer densities rose on all treatments at first but fell again later to much the same levels, leaving similar differences at the end of the season to those in September, 1952. Even on the lime-sulphur plots, where bronzing occurred in 1952 and, to a slight extent, in 1953 on Worcester Pearmain trees, the populations were not important after June, 1952.

After 1951, *M. ulmi* densities did not reach a level where dispersal of mites from plot to plot would be expected. Other factors, including the insect predators and

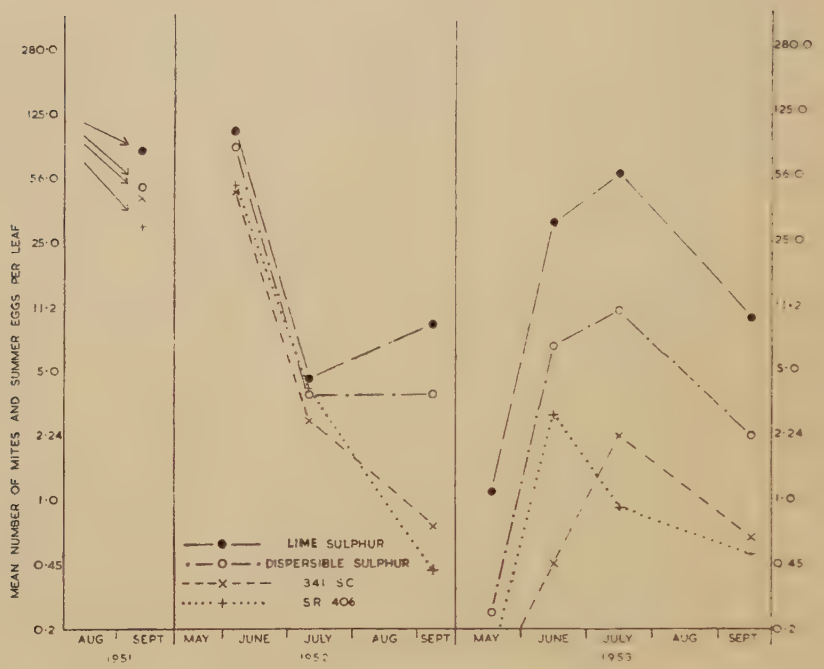

FIG. 1.

Population densities of *M. ulmi*, mites plus summer eggs, for the three seasons.

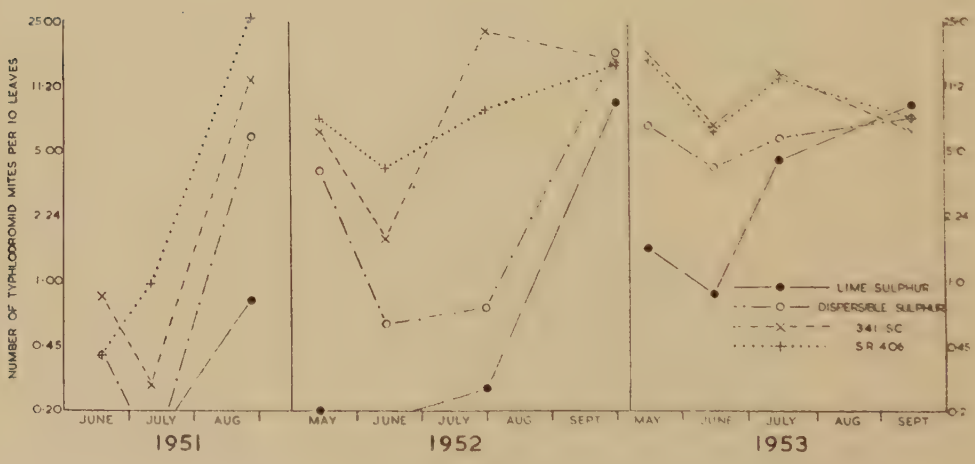

FIG. 2.

Population densities of Typhlodromid mites, mites plus eggs, for the three seasons.

TABLE I.

M. ulmi *population densities : mean numbers of summer eggs + mites per leaf.*

10.9.51		6.6.52		9.7.52		16.9.52	
Lime-sulphur	83	Lime-sulphur	103	Lime-sulphur	5	Lime-sulphur	10
Dispersible sulphur	52	Dispersible sulphur	83	SR406	4	Dispersible sulphur	4
341SC	46	341SC	46	Dispersible sulphur	4	341SC	0·9
SR406	32	SR406	51	341SC	3	SR406	0·4
Significance	P = 0·05	n.s.		P = 0·05		P = 0·001	
19.5.53		**15.6.53**		**15.7.53**		**15.9.53**	
Lime-sulphur	1	Lime-sulphur	31	Lime-sulphur	58	Lime-sulphur	10
Dispersible sulphur	(0·2)*	Dispersible sulphur	7	Dispersible sulphur	11	Dispersible sulphur	2
341SC	0	SR406	3	341SC	2	341SC	0·6
SR406	0·1	341SC	0·4	SR406	0·8	SR406	0·5
Significance	P = 0·05	P = 0·01		P = 0·01		P = 0·001	

Values bracketed together do not differ significantly.

* Excluded from analysis because of variability between replicates.

TABLE II.

M. ulmi *population densities : mean numbers of winter eggs per one inch of wood.*

Treatment	22.11.51		2.12.52		Treatment	6.11.53	
	Red eggs	Total eggs	Red eggs	Total eggs		Red eggs	Total eggs
Lime-sulphur	112	158	16	17	Lime-sulphur	28	31
Dispersible sulphur	66	100	5	5	Dispersible sulphur	7	8
341SC	46	66	0·2	0·2	SR406	5	5
SR406	27	36	0·6	0·6	341SC	1	1
Level of significance	Not sig.	0·05	0·001	0·001		0·001	0·001

increasing numbers of Typhlodromid mites on sulphur plots, probably reduced differences between treatments late in the summer, although at no time was there a complete levelling up.

Fluctuations in the densities of typhlodromid populations.

In 1951 and 1952 direct counts were made of all stages, including eggs, on 25 leaves from each recorded tree on each occasion. In 1953, the mite-brushing machine was used ; this method has the advantage that counts of both *M. ulmi* and other mites, in all stages, can be made on the same leaves and hence on the same day, whereas the leaf-imprint technique was unsuitable for recording the predacious mites. The dominant species found throughout the period of the experiment was *Typhlodromus tiliae* (Oudms.), but the records refer to the totals of all Typhlodromid mites present.

Fig. 2 shows the recorded fluctuations in the density of Typhlodromid mites on each treatment. A logarithmic vertical scale has again been used and Table III should be studied for the significance of differences. The first count, in June, 1951, shows that, as in most commercial orchards in south-east England, Typhlodromid mites were scarce on all recorded trees, none being found where lime-sulphur had been applied. Densities on leaves increased markedly during the summer and there were large differences between treatments by the autumn, that on the lime-sulphur plots being much the lowest. In contrast to 1951, the densities at the first recordings in the two subsequent years, while low on the lime-sulphur plots, were already high on the other treatment plots, especially those receiving the organic fungicides. By autumn, densities evened up at a high level on all treatments ; this might not have occurred to such an extent if adjacent branches of trees had not been touching. There was clearly an adverse effect of lime-sulphur and, to a less extent, of elemental sulphur upon the predacious mites recorded for several weeks after the last application ; such an effect was not shown by the organic fungicides. There is therefore evidence that these mites can multiply rapidly from a low level in the presence of sufficient *M. ulmi* and exist at a higher level throughout the *M. ulmi* season when the spray programme does not act selectively in favour of the pest.

The effects of insect predators.

The relative abundance of insect predators was not often determined but, from the small size of the plots and the nature of the spray materials used, there was no reason to expect important differences between treatments. Occasional records were made on four branches of each recorded tree, using a beating tray, to ascertain the species present and their relative numbers, and to confirm that plot or treatment differences were in fact unimportant (Table IV).

The decrease of *M. ulmi* on all plots in mid-summer 1951 and again in June, 1952, was probably due mainly to the effect of these active, voracious predators which, in the absence of non-selective insecticides, became abundant on all plots during these two years. In total, the populations were similar for all treatments, and it is believed that differences in the abundance of any one species were unimportant, the relatively low density of Black-kneed Capsid on lime-sulphur plots in June, 1952, probably being compensated for by the relatively high density of *O. majusculus*.

Some species of insect predators also feed on winter eggs of *M. ulmi* late into

TABLE III.

Typhlodromid population densities: mean numbers of mites and eggs per 10 leaves.

Treatment	20th June, 1951	10th July, 1951	28th Aug., 1951	7th May, 1952	30th June, 1952	31st July, 1952	28th Sept., 1952	19th May, 1953	15th June, 1953	15th July, 1953	15th Sept., 1953
Lime-sulphur	0·0	0·0	0·8	0·2	0·0	0·2	9	2	0·8	5	9
Dispersible sulphur ..	0·4	0·1	6	4	0·6	0·6	15	7	4	6	8
341SC	0·8	0·2	12	6	2	22	16	17	7	13	6
SR406	0·4	0·9	26	8	4	8	16	17	6	13	8
Level of significance ..	*	Not sig.	P=0·01	*				0·001	0·001	0·001	Not sig.

* Data were not suitable for analysis.

TABLE IV.

Relative abundance of insect predators.

Treatment	Insect	20.6.51	14.9.51	6.5.52	16.6.52	28.5.53
Lime-sulphur	A	17	28	6	92	9
	O	2	45	10	112	1
	B	1	36	—*	26	(P)1
	Total	20	109	16	230	11
Dispersible sulphur	A	23	19	22	96	9
	O	3	31	16	68	1
	B	4	26	—	68	(P)7
	Total	30	76	38	232	17
341SC	A	35	13	24	112	19
	O	1	24	6	52	4
	B	6	27	—	80	(P)21
	Total	42	64	30	244	44
SR406	A	31	12	22	101	13
	O	2	32	4	20	0
	B	2	40	—	72	(P)15
	Total	35	84	26	193	28

A = *Anthocoris nemorum* (L.).
O = *Orius majusculus* (Reut.).
B = *Blepharidopterus angulatus* (Fall.).
P = *Psallus ambiguus* (Fall.).
* *B. angulatus* had not hatched on any plot in May, in 1952 or 1953.

the autumn and again from February or March onwards; but it appears from Table II that this feeding was greater in 1951, when the density of winter eggs was greater, and slight in 1952 and 1953, when comparatively few winter eggs were present, even on lime-sulphur plots.

Typhlodromid mites are not so vulnerable as *M. ulmi* to attack by insect predators, because they do not reach such high densities, are more active and, moreover, have no winter egg stage.

THE INTERACTION OF *M. ulmi* AND TYPHLODROMID POPULATIONS.

The relative multiplication rates of *M. ulmi* and Typhlodromid mites on the same tree are not known and will be ignored in considering the importance of the latter as a natural factor in the control of the red spider mite. It seems obvious, however, that the ratio between the densities of the two types must be more important than the numbers of predacious mites present at any one time, and an attempt has been made to estimate the ratio required for effective predation.

Although counts of *M. ulmi* and Typhlodromid mites were made simultaneously only in 1953, the autumn records, both in 1951 and 1952, were made within a fortnight of each other ; accordingly, they also have been used to obtain the ratios of densities given in Table V.

TABLE V.

Ratio of population densities of M. ulmi *to Typhlodromid mites*

Treatment	Sept., 1951	Sept., 1952	19th May, 1953	15th June, 1953	15th July, 1953	15th Sept., 1953
Lime-sulphur	1,040 : 1	11 : 1	5 : 1	387 : 1	116 : 1	11 : 1
Dispersible sulphur ..	90 : 1	3 : 1	—	18 : 1	18 : 1	3 : 1
341SC	40 : 1	1 : 2	—*	1 : 1·5	1·5 : 1	1 : 1
SR406	10 : 1	1 : 4	1 : 17	5 : 1	1 : 1·5	1 : 1·5

* 1·7 Typhlodromid mites present per leaf but no *M. ulmi* in the sample taken.

The ratio in 1951, even at the end of the season, was extremely unfavourable for control by the predacious mites on the lime-sulphur plots and, to a less extent, on the dispersible sulphur and 341SC plots, whereas on the SR406 plots it was no more than 10 : 1. After the sharp reductions of *M. ulmi* density on all plots in June, 1952, ratios became more favourable, except perhaps on lime-sulphur plots where a ratio of 11 : 1 in September was associated with a higher density of the pest compared with July of that year. It appears that Typhlodromid mites may only give effective control of *M. ulmi* when the pest/predator ratio is rather low, possibly less than 10 : 1 ; it also seems that these predacious mites can flourish in the presence of very low *M. ulmi* densities. The data for 1953 suggest that, where the density of predacious mites exceeds that of *M. ulmi* in mid-May, *M. ulmi* densities later in the season will be kept low but, where the density of *M. ulmi* is the greater at this early stage, a considerable infestation may be expected by mid-summer. The importance of having present as many Typhlodromid mites as possible at petal-fall when *M. ulmi* are beginning to hatch is thus clear. Such a desideratum was not achieved when lime-sulphur was applied in the spring but was achieved when either of the organic fungicides was used ; the results with elemental sulphur were better than with lime-sulphur but inferior to those obtained with the organic fungicides.

DISCUSSION.

Differences, such as those reported between treatments in this paper, cannot be expected to appear in the ordinary commercial orchard where winter washes or highly toxic general insecticides such as parathion are frequently used. No winter wash was applied to the trees in this experiment throughout its duration, and only one application of DDT was made, namely, that applied pre-blossom in 1951. The only other insecticides applied, lead arsenate and nicotine, are reported (Lord, 1949) not appreciably toxic to *Typhlodromus tiliae* (Oudms.). Conditions were thus provided in which Typhlodromid mites could flourish if the fungicides used were not harmful. In fact, these predacious mites built up most quickly and remained at effective levels on the organic fungicide plots. They showed greater fluctuations on the elemental sulphur plots, and lime-sulphur practically eliminated them every

spring. As low densities of predacious mites were associated with high densities of *M. ulmi* on sulphur, especially lime-sulphur plots, the deleterious effects of sulphur outweighed any acaricidal effects.

The spray programme did not suppress the active insect predators, and several species increased appreciably on the high populations of *M. ulmi* present in 1951 and 1952, reducing them markedly by mid-summer. When conditions allowed of a favourable ratio between Typhlodromids and *M. ulmi*, winter egg densities in 1952/53 and 1953/54 were only a fraction of those recorded in 1951/52 and known to be present previously (see Tables II and V). Thus, in the absence of winter washes and non-selective insecticides, insect predators can rapidly reduce high populations of *M. ulmi* to levels of little economic significance. Under the same circumstances, Typhlodromid mites may well increase in number and help to control *M. ulmi*. Adequate populations of the predacious mites are, however, not likely to be present where sulphur fungicides, especially lime-sulphur, are used, but may be expected if fungicides such as 341SC or SR406 are employed. Typhlodromid mites may play a valuable role and be therefore worth conserving, especially as they feed on summer eggs of *M. ulmi* as well as on its active forms and have a life-cycle closely resembling that of *M. ulmi*. In contrast, insect predators prefer mites to eggs and readily move away when mites become scarce (Collyer, 1953c).

SUMMARY.

Two well-established, inorganic fungicides, lime-sulphur and dispersible sulphur, and two new organic fungicides, 2-heptadecylglyoxalidine (341SC) and N-trichloromethylthiotetrahydrophthalimide (SR406), have been applied in normal fungicide schedules for three years on commercial apple trees, Cox's Orange Pippin and Worcester Pearmain on M.II, which received no winter washes. The populations of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), and of the mites of the genus *Typhlodromus* present during the period have been recorded. Approximate figures for populations of insect predators were also obtained.

The density of Typhlodromid mite populations increased in the first year on the organic fungicide plots and, to a less extent, on the dispersible sulphur plots but remained relatively low on the lime-sulphur plots. These densities remained high on the organic fungicides plots, but were reduced each spring on the sulphur fungicides plots. The insect predators were not significantly affected by the fungicides, and populations varied with those of *M. ulmi*. The latter were high at the beginning of the experiment, but insect predators markedly reduced them on all plots, especially in June of the second year. Thereafter, *M. ulmi* remained in check on the organic fungicides plots, but built up sufficiently on lime-sulphur plots to cause bronzing of Worcester Pearmain foliage in the third year.

It appears that a decisive role in the control of *M. ulmi* can be played by Typhlodromid mites only if the ratio of the pest to these predators is low. Indeed, the population density of Typhlodromid mites should exceed that of *M. ulmi* until a considerable proportion of the winter eggs of the latter have hatched (mid-May). If the former are seriously reduced by winter or spring washes, M. *ulmi* is unlikely to be held in check by them.

Only on the organic fungicides plots was a sufficiently low ratio attained and maintained for two years. The ratio on the lime-sulphur plots was always unfavour-

able for control and rose in mid-summer to high values. Ratios on the dispersible sulphur plots were intermediate, but definitely unfavourable in mid-summer.

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PLANT GROWTH REGULATORS

I. THE INFLUENCE OF SIDE-CHAIN LENGTH ON THE ACTIVITY OF ω-(2-NAPHTHYLOXY)-*n*-ALKYLCARBOXYLIC ACIDS FOR THE INDUCTION OF PARTHENOCARPY IN TOMATOES

By L. C. LUCKWILL and D. WOODCOCK
Long Ashton Research Station, Bristol

SYNOPSIS.

2-Naphthyloxyacetic acid (BNOA), having a side-chain 2 carbon atoms long, is highly active in stimulating seedless fruit development in tomatoes. In this paper it is shown that progressive lengthening of the side-chain results in a series of compounds of which only those having an even number of carbon atoms in the side-chain are active. This is thought to be due to the fact that the even carbon compounds are broken down by oxidation in the plant to the active BNOA, whereas those with odd numbers of carbon atoms are broken down to the inactive β-naphthol. It is further shown that the introduction of a chlorine atom at position 3 in the naphthalene nucleus prevents this oxidation. When the side-chain exceeds 6 carbon atoms in length there is a rapid falling off in the activity of the active members of the series, which is probably due to the slower penetration of these long molecules into the cell.

THE work described in this paper is part of an investigation into the relationship between the molecular structure of certain naphthyloxy compounds and their biological activity as growth regulating substances. During recent years a considerable amount of work on this aspect of the subject has been published for other series of growth-substances, particularly the indolyl and phenoxy series, but no systematic investigation of the naphthyloxy compounds as growth regulators has yet been reported. One reason for this is doubtless the low activity of this series of compounds in the two tests which have been most widely used for measuring growth-substance activity, viz. the *Avena* curvature test and the coleoptile cylinder test. However, 2-naphthyloxyacetic acid is active in delaying the abscission of petioles (e.g. of *Coleus*) and in stimulating parthenocarpy in tomatoes and, in this investigation, the latter property was utilized to measure the biological activity of these compounds.

In this paper attention is confined to a series of homologues of 2-naphthyloxyacetic acid, $C_{10}H_7.O.(CH_2)_n.COOH$, in which n varies from 1 to 11, giving compounds in which the side-chain varies from 2 to 12 carbon atoms in length. The effect of a chlorine atom at position 3 in the naphthyloxy nucleus was also investigated. A subsequent paper in this series will describe the effect on biological activity of nuclear halogen substitution at other positions.

MATERIALS.

The experimental work involved in the synthesis of the ω-(2-naphthyloxy) alkylcarboxylic acids used in this investigation has been described by Pope and Woodcock (6). Two main routes of synthesis were employed :

(A) $C_{10}H_7ONa \rightarrow C_{10}H_7O(CH_2)_nBr \rightarrow C_{10}H_7O(CH_2)_nCN \rightarrow C_{10}H_7O(CH_2)_nCOOH$

(B) $C_{10}H_7O(CH_2)_nCH(CO_2H)_2 \rightarrow C_{10}H_7O(CH_2)_{n+1}COOH$

Where the appropriate polymethylene dibromide was readily available it was used in the route (A) ; in other cases a malonic ester synthesis (B) starting from the 2-naphthyloxy alkyl bromide with two carbon atoms less than the final side-chain, led to the required acid. β-(2-Naphthyloxy)- and β-(3-chloro-2-naphthyloxy)-propionic acids were, however, more conveniently obtained by condensation of the sodium salt of the naphthol with β-propiolactone (1).

An interesting example of what appears to be dimorphism was observed with ε-(2-naphthyloxy)-caproic acid. Two forms, m.p.s. 94-95° C. and 126-127° C. which do not mutually depress, have been obtained and all attempts at interconversion have so far failed. Both forms have been tested and have proved equally active in the tomato ovary test.

Owing to limited solubility of many of the acids in water all compounds were tested as sodium salts.

Measurement of biological activity.

Biological activity was measured by observing the rate of growth of unpollinated tomato ovaries following treatment with known amounts of each compound. The details of the method have been described in a previous publication (Luckwill, 5).

The sodium salt of the acid to be tested was dissolved in water at a concentration of 3,000 parts per million and from this solution was prepared a series of dilutions of strength 1,000, 300, 100, 30, 10, 3 and 1 p.p.m. Some of the compounds, as indicated in Table I, proved insoluble at 3,000 p.p.m. and could only be tested over the lower range of concentrations. In general, the solubility of the sodium salts in water decreased with increasing length of the side-chain, the three highest members of the series being particularly insoluble.

An in-bred line of the tomato variety " Blaby " (Line 107) was used throughout the tests, which were carried out under normal glasshouse conditions. For each test between 75 and 100 plants were arranged in five randomized blocks and were prepared as described in a previous publication (Luckwill, 5). By means of a hypodermic syringe, 0·0225 ml. (3 drops) of each dilution of the substance to be tested was placed on each of a series of 10 ovaries and allowed to dry. After seven days the diameters of the young fruits were measured. Each test included, in addition to water controls, a complete series of ovaries treated with 2-naphthyloxyacetic acid at concentrations ranging from 1 to 1,000 p.p.m., against which the activities of all the other compounds were assessed. For each test probit-response/dosage lines were drawn by eye from which the median effective dose (ED50) of each compound was estimated. The activity of the compound relative to that of 2-naphthyloxyacetic acid (2-NOA) was expressed as :

$$\frac{\text{ED50 of 2-NOA in same test}}{\text{ED50 of compound under test}} \times \frac{M1}{M2} \times 1{,}000$$

where M1 is the molecular weight of the compound under test and M2 that of Na2-NOA. Between three and five separate tests were carried out with each compound which showed activity.

Owing to the low biological activity and the low solubility of the two highest members of the series ι-(2-naphthyloxy)decanoic acid and λ-(2-naphthyloxy) dodecanoic acid, the ED50's were well above the highest concentrations of these

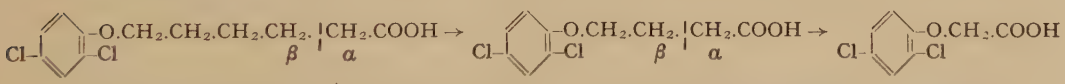
compounds it was possible to test, and were estimated indirectly by extrapolation of the probit lines. The results are presented in Tables I and II.

DISCUSSION.

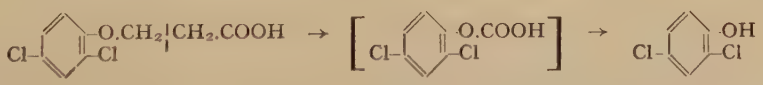
An outstanding feature of this investigation is the complete lack of activity of those naphthyloxy acids having an odd number of carbon atoms in the fatty side-chain. By contrast, γ-(2-naphthyloxy)-butyric acid and ϵ-(2-naphthyloxy)-caproic acid with four and six carbon atoms respectively in the side-chain proved as active in this test as 2-naphthyloxy-acetic acid itself, whilst η-(2-naphthyloxy)-octanoic acid, ι-(2-naphthyloxy)-decanoic acid, and λ-(2-naphthyloxy)-dodecanoic acid with eight, ten and twelve carbon atoms respectively also showed definite though considerably reduced activity.

This phenomenon of alternation of growth-regulating activity has been previously reported for other homologous series of growth substances. Thus Thimann and Bonner (8) noticed an alternation in activity (as measured by the *Avena* test) in the indolyl series, $C_8H_6N(CH_2)_nCOOH$ (where n varies from 0-4), and Grace (3), investigating the naphthylacetic acids, $C_{10}H_7(CH_2)_nCOOH$ found greater root inducing activity with the acids where n was even, though a general decrease in activity with increasing side-chain length was apparent. More recently Synerholm and Zimmerman (7) report a similar phenomenon in the first seven members of the ω-(2 : 4-dichlorophenoxy) aliphatic acid series. These authors also tested the first three members of the ω-(2-naphthyloxy) series and found β-(2-naphthyloxy)-propionic acid to be inactive for cell elongation in the tomato leaf epinasty test.

Synerholm and Zimmerman (7) put forward an hypothesis to account for these results based on an analogy with the oxidation of fatty acids in animal metabolism, where it is known that oxidation normally occurs at the β-carbon atom, leading to the formation of an acid with two fewer carbon atoms. Thus it was postulated that a compound such as ϵ-(2 : 4-dichlorophenoxy)-caproic acid (with 6 carbon atoms in the side-chain) was active as a growth regulator, because by successive β-oxidations it could be converted by the plant to the biologically active 2 : 4-dichlorophenoxy acetic acid.



Those members of the series with an odd number of carbon atoms, on the other hand, would be oxidized via the hypothetical carbonate to 2 : 4-dichlorophenol, which is inactive as a growth regulator.



Evidence for the production of phenol in flax plants treated with those ω-phenoxyalkyl carboxylic acids with an odd number of carbon atoms in the side-chain has been given by Fawcett, Ingram and Wain (2). At present, however, there is no direct evidence that β-oxidation within the plant can result in the breaking down of compounds with an even number of carbon atoms in the side-chain.

The results presented in this paper for the naphthyloxy acids are in good agreement with those of Synerholm and Zimmerman (7) for the phenoxy acids and it seems likely that a similar mechanism is operative. The reduced activity of the 8, 10 and 12 carbon atom members compared with 2-naphthyloxyacetic acid requires special comment, since, if the β-oxidation hypothesis is correct, these compounds, like the 4 and 6 carbon members, would be expected to show a relative molar activity of 1,000. As can be seen from Table I, there is a marked falling off in the water solubility of the compounds having more than 8 carbon atoms in the side-chain. It seems unlikely, however, that this can be considered as a contributory cause of their lower activity, for even at concentrations at which they formed true solutions in water, their activity was much less than would have been expected on the assumption of complete oxidation to 2-naphthyloxyacetic acid. Further confirmation of the fact that biological activity and water solubility are not directly related is provided by the two dimorphic forms of ϵ-(2-naphthyloxy)-caproic acid, which, in spite of a very great difference in solubility, both gave an activity of 1,000 in the tomato parthenocarpy test. The solubility of the higher melting point dimorph of this compound is, in fact, somewhat less than that of the almost inactive dodecanoic acid.

In compounds with eight and ten carbon atoms in the side-chain a certain amount of oxidation may take place at the naphthyloxy end of the chain (i.e. on the ω-carbon atom). The phenomenon of ω-oxidation is known from studies on animal metabolism to occur with those fatty acids having 8 to 11 carbon atoms. Assuming this phenomenon to take place also in plant tissues as suggested by Fawcett *et al.* (2), the following type of breakdown would occur in the 8 and 10 carbon members of the present series :

η-(2-naphthyloxy)-n-octanoic acid — β-naphthol — suberic acid.

Whilst it would be possible, on the assumption of ω-oxidation, to account for the reduced activity of the octanoic and decanoic acids, this hypothesis would not be acceptable for the dodecanoic acid, where ω-oxidation should not occur.

It seems more probable that the falling off in activity of the 8, 10 and 12 carbon acids is due primarily to restrictions on the penetration of these molecules through the plasma membranes imposed by the great length of their fatty side-chains, rather than to any differences in their primary activity at the site of action in the cytoplasm. If this is so the very sudden drop in activity between the 6 and the 8 carbon acids would imply that there is some critical side-chain length below which penetration is not affected and above which it becomes the factor limiting the overall biological activity of the molecule.

Studies on the effect of nuclear chlorine substitution in 2-naphthyloxyacetic acid, to be reported fully in a subsequent paper, have shown that the biological activity of this molecule is unimpaired by the introduction of a chlorine atom at position 3. It is interesting to observe, therefore, that in the higher homologues of this series, the activity of the butyric, caproic, octanoic and decanoic acids is completely destroyed by a chlorine atom in this position (Table II). On the assumption that the activity of the unsubstituted acids is due to β-oxidation, it would therefore appear that the introduction of a chlorine atom at position 3 in

TABLE I.

Relative molar activities of a homologous series of ω-(2-naphthyloxy)-n-alkylcarboxylic acids in the tomato ovary test.
(All compounds tested as sodium salts.)

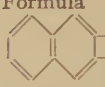
Name	Formula R =	m.p. (°C.) of acid	Solubility of Na salt in water at 25-27° C. p.p.m.	Relative molar activity at ED50
2 Naphthyloxyacetic acid	$R.CH_2COOH$	155-156°	6,550	1,000
β-(2-Naphthyloxy)-propionic acid	$R(CH_2)_2COOH$	143-144°	7,650	0
γ-(2 Naphthyloxy)-butyric acid	$R(CH_2)_3COOH$	122-123°	5,900	1,000
δ-(2-Naphthyloxy)-valeric acid	$R(CH_2)_4COOH$	111-112°	5,300	0
ε-(2-Naphthyloxy)-caproic acid	$R(CH_2)_5COOH$	126-127°*	3,750	1,000
		94-95°	45	1,000
ζ-(2-Naphthyloxy)-heptanoic acid	$R(CH_2)_6COOH$	96-97°	6,100	0
η-(2-Naphthyloxy)-octanoic acid	$R(CH_2)_7COOH$	91-92°	6,650	180
θ-(2-Naphthyloxy)-nonanoic acid	$R(CH_2)_8COOH$	98-99°	2,250	0
ι-(2-Naphthyloxy)-decanoic acid	$R(CH_2)_9COOH$	114-115°	500	2†
λ-(2-Naphthyloxy)-dodecanoic acid	$R(CH_2)_{11}COOH$	96-97°	70	< 1†

* Two dimorphic forms of this compound were tested.
† ED50 estimated by extrapolation of probit line.

some way blocks this oxidation process. A similar phenomenon has previously been reported, though without comment, by Synerholm and Zimmerman (7). These authors found that γ-(2 : 4-dichlorophenoxy)-butyric acid, as would be expected, was active as a growth regulator, as was also 2 : 4 : 5-trichlorophenoxy acetic acid : but γ-(2 : 4 : 5-trichlorophenoxy)-butyric acid, which should be active, was not. Here again the implication is that the introduction of the extra chlorine atom in the 5 position has blocked the β-oxidation of this latter compound. It is not possible to say at present how such blockages might be caused, and it is clear that any explanation proposed would have to take into account the spatial configuration of the carbon atoms in the side-chain of these molecules, a subject on which there is at present no information.

TABLE II.

Relative molar activities of certain ω-(3-chloro-2-naphthyloxy)-n-alkylcarboxylic acids in the tomato ovary test. (All compounds tested as sodium salts.)

Name	Formula R′ = 	m.p. (°C.) of acid	Relative molar activity at ED50
(3-Chloro-2-naphthyloxy)-acetic acid ..	$R'CH_2COOH$	*182-183°	1,000
β-(3-Chloro-2-naphthyloxy)-propionic acid ..	$R'(CH_2)_2COOH$	173-174°	0
γ-(3-Chloro-2-naphthyloxy)-butyric acid ..	$R'(CH_2)_3COOH$	174-175°	0
ε-(3-Chloro-2-naphthyloxy)-caproic acid ..	$R'(CH_2)_5COOH$	114-115°	0
η-(3-Chloro-2-naphthyloxy)-octanoic acid ..	$R'(CH_2)_7COOH$	74-75°	0
ι-(3-Chloro-2-naphthyloxy)-decanoic acid ..	$R'(CH_2)_9COOH$	90-91°	0

* James and Woodcock (1951).

SUMMARY.

1. Ten members of the homologous series of ω-(2-naphthyloxy)-n-alkyl carboxylic acids and six members of the corresponding 3-chloro-2-naphthyloxy series were prepared. The biological activity of the sodium salts of these acids was measured by their ability to induce parthenocarpic development of unpollinated tomato ovaries.

2. In the non-halogenated series it was found that only those members having an even number of carbon atoms in the side-chain were active as growth regulators. It is considered that this result can be explained on the β-oxidation hypothesis proposed by Synerholm and Zimmerman (7).

3. The acids with 4 and 6 carbon atoms in the side-chain were as active as 2-naphthyloxyacetic acid, but further increases in the length of the side-chain led to a very marked falling off in activity. It is suggested that this is due to restrictions on the penetration of these molecules into the cell, imposed by the great length of their fatty side-chains.

4. The introduction of a chlorine atom in the 3 position in the naphthalene nucleus did not affect the activity of 2-naphthyloxyacetic acid, but completely destroyed the activity of the higher homologues in the series, presumably by blocking the β-oxidation process.

ACKNOWLEDGMENTS.

The authors wish to thank Mrs. P. M. Pope for determining the solubilities of the compounds given in Table I, and for the preparation of the sodium salts of the acids.

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THE INFLUENCE OF SOURCE AND GROWTH SUBSTANCE ON THE BEHAVIOUR OF APPLE AND PLUM CUTTINGS

By R. J. GARNER* and E. S. J. HATCHER†

*East Malling Research Station, Kent †Research Institute of Plant Physiology, London

SYNOPSIS.

The behaviour of hardwood cuttings is influenced by factors that have operated upon the parent plant. A comprehensive study, not only of such "source" effects but also of their interaction with growth substance treatment and subsequent environment, aims to extend this method of propagation. Patterns of behaviour of varieties of very different rooting capacity are clearly related, layer cuttings being better than hedge, with a declining gradient from the base of the shoot. The etiolated basal cutting from a layer shoot normally roots well whenever planted, but non-etiolated cuttings derive considerable benefit from over-wintering in soil.

With the readily rooting Myrobalan B, growth substance application in the autumn is not essential; such treatment is advocated for the moderately rooting Brompton plum while, with the shyly rooting Crab C, accelerative influence has, so far, proved inadequate. Success with Crab C could derive from the ability of the cutting to survive, though unrooted, into the second year when rooting normally follows. Spring planting and absence of growth substance stimulation enhance this chance.

Brompton cuttings have medium power to survive, whereas Myrobalan B cuttings have only low, so that they are liable to succumb when conditions are adverse. The survival factor may contribute considerably towards the rooting gradient and must be distinguished from inherent rooting capacity.

When the rooting of non-etiolated cuttings is satisfactory the relative disparity of hedge compared with layer cuttings diminishes, and hedge culture is highly favoured for supplying cuttings.

Elevation of hitherto shy-rooting varieties to high levels depends upon further adjustment both of growth substance treatment and subsequent environment.

THE problems of propagating fruit tree rootstock varieties by hardwood stem cuttings have long been defined (Knight, 1926), and at East Malling have engaged the attention of a series of investigators (Knight and Witt, 1927; Pearse, 1939; Vyvyan, 1943; and Hatcher and Garner, 1948). Up to 1933 research was concerned primarily with the cutting in its nursery environment while, from 1935 to 1939, the effects of synthetic hormonal substances were examined intensively. Now the interactions of these factors with those operating through the source plant are being studied.

The cutting is normally taken from the current season's growth of plants established in the nursery, these plants having themselves been multiplied vegetatively over a long period. The principal sources of cuttings are layered plants, hedges, and plants newly established in nursery rows, each of their yearling shoots yielding several cuttings, usually, though not invariably, taken in the autumn.

The first comparison of cuttings taken from these different cultural sources was made with Myrobalan B plum, a variety which roots readily and is not uncommonly used as a hedge plant. It was found (Sinha and Vyvyan, 1943) that cuttings from the older established layer and hedge plants were much superior to those from young plants recently established from layers or cuttings. This prompted the production of hedges specifically for providing cuttings, in the first instance of three rootstock varieties especially selected for detailed studies.

These rootstocks were Myrobalan B, notable for its ease of rooting and providing the link with the earlier source experiment, Brompton plum, known to root moderately well and valued for its wide compatibility with scion varieties, and Crab C apple, so shy to root, even on the layer bed, that it was withheld from the commercial nursery despite its excellent qualities as a vigorous rootstock (Garner, 1946).

By 1947 these young hedges were supplying adequate shoots for experimental purposes and a comparison of cuttings from hedge and layer shoots, of all three varieties was for the first time possible. This series of experiments forms the main part of the present paper, but earlier experiments are also included, one with Myrobalan B designed to separate the inherent size factor from the effect of position in the shoot, others with Crab C, exploring its rooting from sources then available.

At any time, only one growth substance treatment was given. The substance used was indole-3-butyric acid (IBA), applied as an instantaneous alcoholic dip, the concentration determined in the light of concentration trials (Hatcher and Garner, 1951).

The cutting technique was essentially that of Knight *et al.* (1928) with certain modifications. The cuttings were longer, 30 cm. instead of 20-25 cm., no attention was given to bud position when making lower cuts, planting was deeper, with only 5 cm. above ground, and no sand was placed at the bottom of the cutting. Furthermore, following spacing trials, the cuttings were planted more closely in the main experiments, with 15 cm. between rows and only 5 cm. within rows.

The purpose of this part of the general investigation was to elucidate the basic behaviour patterns of the selected rootstocks in relation to varietal characteristics, cultural origin, the portion of the shoot used and the growth substance treatment given. It may be regarded as the foundation for later work.

Myrobalan B plum source experiment.

Description of experiment.

This was a detailed comparison of cuttings from hedge and layer shoots. Two grades of shoot were chosen, thick and thin, averaging 103 and 85 cm. in length respectively, and two contiguous cuttings were taken. From the hedge shoots these were the basal and second cuttings but, from the layer shoots, the second and third cuttings were used, to avoid the earthed-up etiolated region. Even so, girth advantage was with the layer cuttings despite their higher position (see diameter measurements, Table I).

Cuttings were planted on 8th October, 1942, with no growth substance treatment, on three plots, one on loam soil of the Barming Series, Hythe Beds (Furneaux, 1954), the other two at the drier (east) and wetter (west) ends of a delta lying some 18 in. higher than the deeper parts of a recently drained lake bed, which was used as an experimental nursery. Later the delta was reconstructed into a terraced island (Garner and Hatcher, 1949). A Latin Square lay-out was used, the unit plot a double row containing fifty cuttings. A census was taken the following April, and final records included counts of rooted, surviving and dead cuttings as well as shoot growth measurements.

Results.

By 12th April, cuttings had opened their buds and shoot extension had begun. On the delta plots there was considerable wilting of the young shoots, which

TABLE I.

The rooting behaviour (percentage rooted) of Myrobalan B cuttings from different sources, planted in two soils, in relation to the size of cutting.

		Thick			Thin			Mean
		Basal	Second	Third	Basal	Second	Third	
Hedge	Loam	46·0	72·5	—	76·0	58·0	—	63·1
	Delta E	82·0	70·5	—	74·5	4·0	—	57·7
	Delta W	60·5	42·5	—	63·4	6·5	—	43·2
	Mean	62·8	61·8	—	71·3	22·8	—	
Layer	Loam	—	32·0	63·0	—	70·5	64·5	57·5
	Delta E	—	37·5	19·5	—	43·5	5·0	26·4
	Delta W	—	43·0	20·0	—	40·0	2·0	26·2
	Mean	—	37·5	34·2	—	51·3	23·8	
Diameter (mm.)	Hedge	7·4	6·2	—	5·3	4·5	—	
	Layer	—	7·8	6·6	—	6·7	5·5	
Growth per cutting (cm.)	Loam	94	87	—	75	68	—	
	Delta	—	138	137	—	115	117	

examination of sample cuttings showed to be associated with rotting of the basal tissues. Upper cuttings, especially from thin shoots, were most affected. On the loam most cuttings were healthy but, again, the upper cuttings from the thin shoots were most prone to wilting.

Final rooting percentages (Table I) show clearly the markedly lower values on the delta plots, especially on the wetter one. Upper cuttings from thin shoots rooted negligibly while, of their lower counterparts, those from layers rooted moderately and those from hedge quite well, even with their smaller girth. This points to a positional superiority of basal cuttings over seconds in withstanding such unfavourable conditions. On the loam, all thin cuttings rooted well, with significantly more lower cuttings doing so than upper but with no overall difference between hedge and layer. As, however, hedge cuttings had the position advantage the inference is that the layer is the better source.

Passing to thick shoots, cuttings from an upper position planted on the delta rooted much better than did the corresponding cuttings from thin shoots, indicating greater resistance to the damaging influence. Upper hedge cuttings were least affected, again reflecting positional superiority, this time of a second cutting over a third. On the loam, all upper cuttings rooted moderately well, though the same trend is still visible. Regarding the lower position, basal hedge cuttings, wherever planted, always rooted more prolifically than did second layer cuttings, again demonstrating a position dominance over girth. But whereas, on the delta plots, lower cuttings were always significantly better than their contiguous neighbours above, on the loam plot quite the reverse held, because of depressed rooting of the very thick cuttings. Evidently there is an optimum girth above which rooting declines, though

the level of this optimum must depend on conditions and was apparently not passed on the delta. Possibly, however, the low rooting of the thick second layer cuttings in these conditions was due to their excessive girth, the effect being masked by very poor rooting of the third cutting.

The satisfactory performance of basal cuttings on the delta soil, whatever their relative girth, is noteworthy and suggests that, given initial tolerance of rather adverse conditions, there is subsequent benefit from an environment suited to root and shoot development, whereas, on the loam soil, thick cuttings experience a decided set-back, compared either to their basal equivalents from thin shoots or to their contiguous counterparts. In keeping with this is the much greater amount of growth on the delta plots (Table I) and the superior growth of thick cuttings compared with that of the thin. Positional and source effects on growth were, however, quite small.

This experiment has confirmed the hedge shoot to be a good cutting source for Myrobalan B, with no simple comparison with layer shoots being possible owing to position and girth complexities. Hedge shoots are probably superior in the sense that they provide cuttings less likely to exceed the optimum girth size, though, of course, if too thin, the cuttings may fail to tolerate conditions less suited to them, whereas in favourable conditions they suffer no such disadvantage.

Experiments with Crab C apple.

Description of experiments.

Three exploratory experiments involved taking cuttings from different shoot positions and comparing their rooting and survival behaviour. In the first, four contiguous cuttings were taken from non-rooted layer shoots in March, 1943, and in the other two, basal, middle and apical cuttings from layers and bedded stocks. In 1944-45 the cuttings were planted on 15th December and, in 1945-46, on 30th November ; in the latter instance IBA dip treatment of 5 mg. per ml. was applied. All experiments were planted on the delta.

Results.

The 1943 experiment was described earlier (Garner and Hatcher, 1948) and the results are now summarized in Table II. After one year, 55 per cent. of the etiolated basal cuttings had rooted but very few others. After removal of all grown shoots, the experiment was then left a further year, with the result that many surviving

Table II.

The behaviour of Crab C cuttings from different parts of the shoot.

Origin of cuttings. (Part of the shoot)	Percentage rooted		Wood growth (cm.)	
	1st year	2nd year	1st year	2nd year
Apical	0	31	—	55
Third	0	81	—	70
Second	2·5	84	22	105
Basal	55	95	70	280

cuttings rooted, including apical ones. A shoot gradient was still apparent, especially in the growth made.

In both the later experiments (Table III), basal layer cuttings rooted and survived best ; middle and apical cuttings from the same shoots mostly died. Without growth substance, about half the basal layer cuttings rooted and the remainder survived ; with growth substance, rooting was complete. Nearly all the cuttings from shoots of young bedded plants failed to root or survive.

TABLE III.

The rooting and survival behaviour of Crab C cuttings from shoots of different cultural origin.

		*	Layers			Bedded stocks		
			Basal	Middle	Apical	Basal	Middle	Apical
Percentage rooted :	1944–45	O	45	0	0	0	0	0
	1945–46	O	45	0	0	2	0	0
		G	100	8	0	3	0	0
Percentage surviving :	1944–45	O	55	19	14	12	4	9
	1945–46	O	55	0	8	2	7	0
		G	0	2	3	2	0	0

* G = Treated with growth substance.
O = Not treated.

The significant feature in the first of these experiments was the high number of cuttings which survived and, in the other two experiments, the low number, other than of basal layer cuttings, which survived. A further feature, again with the exception of the basal layer cuttings, was the failure to root even after growth substance treatment. The high survival in the earliest experiment may have been because the cuttings were not taken until the spring.

THE BASIC BEHAVIOUR PATTERNS OF THE SELECTED ROOTSTOCK CUTTINGS.

Description of experiments.

These comparative experiments were conducted in 1947-48 using Myrobalan B, Brompton and Crab C. Apical, middle and basal cuttings were taken from hedge and layer shoots of one medial grade on two occasions, autumn and spring, and planted on the delta. A standard growth substance treatment, IBA dip of ½ mg. per ml., was systematically applied. The experimental lay-out for each variety consisted of replicated blocks, the six cutting types (three positions from each of two sources) forming the randomized main plots, sub-plots being the four planting time/growth substance combinations.

In autumn, cuttings were made and planted during the first week in November ; for spring planting the plum cuttings were taken in mid-February, though snow delayed planting a fortnight ; the apple cuttings were taken a month later.

Length and girth measurements were made on samples of 50 shoots, the latter at the mid-points of the three cuttings (Table IV).

Table IV.

Experiments determining the basic behaviour patterns of the selected rootstocks, (i) the lengths of the source shoots and the initial diameters of the cuttings.

Variety	Source	Length of shoot (cm.)	Diameter of cuttings (mm.)		
			Basal	Middle	Apical
Myrobalan B	Hedge	137	7·2	5·2	2·8
	Layer	135	8·3	5·3	2·7
Brompton	Hedge	115	8·5	6·4	3·7
	Layer	129	10·2	6·5	3·5
Crab C	Hedge	114	8·5	6·4	3·9
	Layer	105	7·9	5·8	3·8

In early summer the condition of the cuttings was recorded, and final records made at the completion of one season's growth.

Results.

Establishment of cuttings (percentage rooted). The rooting values are presented in Table V, average percentages being Myrobalan B 45·3, Brompton 39·7 and Crab C 16·1, which indicate the broad varietal differences. Separate statistical analyses have been made for each variety, the main effects of cultural source, portion of shoot, occasion of planting and growth substance treatment always being significant, as were the first order interactions between portion of shoot and cultural source, and occasion of planting and growth substance treatment.

Layer was consistently a better source than hedge, the relative difference between them being least with Myrobalan B, greatest with Crab C. There was marked influence of portion of shoot and a basipetal gradient, the dominance of basal cutting rooting being strongest with Crab C, and weakest with Myrobalan B. With the plums, more than twice as many cuttings rooted following autumn planting than spring but, with the apple, more cuttings rooted after spring planting.

Comparing hedge and layer for each position brings out the superior rooting of the basal layer cutting ; the emphasis diminishes with increasing rooting capacity and is least in Myrobalan B. This same emphasis shows even more dramatically relative to occasion. After autumn planting many upper plum cuttings root but, following spring planting, the number is greatly reduced. Hedge basal cuttings show a similar reduction but not the layer basal cuttings ; indeed, with increasing shyness to root, as in the apple, a positive advantage comes from leaving the layer shoot attached until spring. The great propensity for rooting of the basal layer cutting is ascribed to the favourable root-inducing conditions of soil-etiolation at the base of the shoot during growth.

The effects of growth substance varied. With the readier rooting Myrobalan B, basal cuttings gave a positive response especially marked in hedge cuttings taken in spring ; the increase in percentage rooting from 37 to 82 compensated for later planting. With middle and apical cuttings such treatment reduced rooting, suggesting

TABLE V.

Experiments determining the basic behaviour patterns of the selected rootstocks, (ii) the percentages of rooted cuttings.

Variety	Source	*	Autumn planting			Mean	Spring planting			Mean
			Basal	Middle	Apical		Basal	Middle	Apical	
Myrobalan B	Hedge	O	80	82	5	55·7	37	18	0	18·3
		G	90	67	2	53·0	82	13	0	31·7
	Layer	O	92	93	27	70·6	85	12	0	32·3
		G	100	88	10	66·0	98	7	0	35·0
	Mean		90·5	82·5	11·0	61·3	75·5	12·5	0·0	29·3
Brompton	Hedge	O	60	35	30	41·7	15	2	0	5·7
		G	82	35	22	46·3	40	5	3	16·0
	Layer	O	82	65	45	64·0	87	8	0	31·7
		G	83	82	43	69·3	95	10	3	36·0
	Mean		76·7	54·2	35·0	55·3	59·2	62·5	1·5	22·3
Crab C	Hedge	O	13	0	0	4·3	15	0	0	5·0
		G	23	2	0	8·3	27	2	0	9·7
	Layer	O	53	0	0	17·7	77	2	2	27·0
		G	57	7	0	21·3	82	20	5	35·7
	Mean		36·5	2·2	0·0	12·9	50·2	6·0	1·7	19·3

* G = Treated with growth substance.
O = Not treated.

a toxic concentration. Basal hedge cuttings of Brompton likewise benefited, even with autumn planting, and an autumn response by the second layer cuttings showed that growth substance was in this case not too strong. With Crab C, the general effect of treatment was so limited, even with the basal layer cuttings, that the need of a much higher concentration is indicated.

It is pertinent to contrast the three varieties in relation to the performance of hedge cuttings (Fig. 1), since their root initiation is in no way induced prior to separation from the source plant. With the plums, effective rooting was obtained after autumn planting, both with basal and middle cuttings. Myrobalan B rooted more prolifically than did Brompton, except with the apical cutting which doubtless was more prone to the damaging influence of the delta soil due to its small girth (Table IV). This same propensity to damage is also manifest in the unfavourable reaction to growth substance. Crab C hedge cuttings did not root effectively.

Survival of non-rooted cuttings. Interest in cuttings failing to rank as rooted (criterion less than 5 cm. growth) had been aroused by the earlier experiments with Crab C apple, which revealed that, after spring planting, such cuttings may develop roots in the second season (Table II). Accordingly the later experiments were designed to clarify this point, and in Table VI the percentages of surviving cuttings are given.

The average values were 3·5, 28·1 and 45·2 respectively for Myrobalan B, Brompton and Crab C, which is the reverse of the rooting order. Table VI also shows

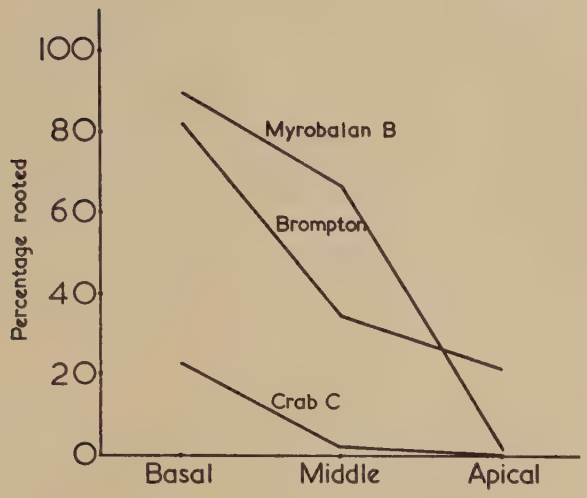

Fig. 1.

Rooting of hedge cuttings planted in autumn after growth substance treatment.

Table VI.

Experiments determining the basic behaviour patterns of the selected rootstocks, (iii) the percentages of surviving cuttings.

Variety	Source	*	Autumn planting			Mean	Spring planting			Mean
			Basal	Middle	Apical		Basal	Middle	Apical	
Myrobalan B	Hedge	O	5	2	0	2·3	17	8	0	8·3
		G	0	0	0	0·0	0	7	0	2·3
	Layer	O	8	2	0	3·3	10	23	0	8·3
		G	0	0	0	0·0	0	2	0	0·7
	Mean		3·2	1·0	0·0	1·4	6·7	10·0	0·0	5·6
Brompton	Hedge	O	15	27	38	26·7	20	37	42	33·0
		G	7	30	40	25·7	32	32	32	32·0
	Layer	O	8	32	30	23·3	12	68	37	39·0
		G	2	12	23	12·3	3	58	42	34·3
	Mean		8·0	25·2	32·7	22·0	16·7	48·7	38·2	34·6
Crab C	Hedge	O	68	62	25	51·7	82	93	38	71·0
		G	48	35	12	31·7	65	67	23	51·7
	Layer	O	40	43	35	39·3	23	95	48	55·3
		G	43	25	10	26·0	8	73	25	35·3
	Mean		49·7	41·2	20·5	37·2	44·5	82·0	33·5	53·3

* G = Treated with growth substance.
O = Not treated.

that many more cuttings survived after spring than after autumn planting, but growth substance treatment reduced survival.

With Brompton, the increased survival after spring planting only partly compensates for the reduced rooting, and autumn planting thus remains the more effective. But with Crab C, both rooting and survival were favoured by taking the cuttings in spring. So few hedge cuttings rooted, however, that the survival factor was dominant. Two points should be noted, that apical cuttings displayed inferior survival, and that though spring planting led to greater survival, even autumn values were appreciable.

Growth of cuttings. Growth data are summarized in Table VII and comment is given on each rootstock separately.

TABLE VII.

Experiments determining the basic behaviour patterns of the selected rootstocks, (iv) shoot growth of rooted cuttings (cm.).

Variety	Source	*	Autumn planting			Mean	Spring planting			Mean
			Basal	Middle	Apical		Basal	Middle	Apical	
Myrobalan B	Hedge	O	59	55	40	51·3	31	26	—	28·5
		G	85	63	74	73·0	46	31	—	38·5
	Layer	O	81	50	36	55·7	50	31	—	40·5
		G	97	63	50	70·0	55	27	—	41·0
	Mean		80·5	57·7	50·0	62·7	45·5	28·7	—	37·1
Brompton	Hedge	O	52	37	30	39·7	11	17	—	14·0
		G	65	50	38	51·0	29	10	17	18·7
	Layer	O	97	33	23	51·0	47	9	—	27·5
		G	110	34	38	60·7	56	15	8	26·3
	Mean		81·0	38·5	32·2	50·6	35·7	12·5	12·5	21·8
Crab C	Hedge	O	48	—	—	48·0	33	—	—	33·0
		G	35	19	—	25·5	34	12	—	23·0
	Layer	O	46	—	—	46·0	44	18	22	28·0
		G	59	36	—	47·5	52	20	11	27·7
	Mean		47·0	27·5	—	40·5	40·7	16·7	16·5	27·3

* G = Treated with growth substance.
O = Not treated.

Statistical analysis of the Myrobalan B values revealed significant effects of all the main factors and their first order interactions. Basal layer cuttings exceeded basal hedge ; autumn planting resulted in much more growth than spring planting ; there was a growth gradient increasing to the basal cutting ; and growth substance treatment had a stimulating effect, greater in autumn than spring, in the basal cuttings than in others, and in hedge cuttings than in layer.

Except for the basal layer, spring planted Brompton cuttings grew little and, as in Myrobalan, the superiority of layer over hedge was limited to basal cuttings. Again there was a position gradient and an overall growth substance increase from 45·4 to 57·1 cm. All these effects were significant.

The Crab C data reveal a definite stimulatory effect of growth substance on the basal layer cuttings but not elsewhere. The extent of growth was limited and there was little difference between autumn and spring planted cuttings, this resembling the absence of autumn superiority in rooting.

Early summer observations on cuttings. By late May the apical Myrobalan cuttings were in many cases wilting or dead and, of the remainder, the main contrast was between autumn planted and spring planted cuttings, most of the former having sprouted.

Most Brompton and Crab C cuttings were at this time quite healthy, with the proportion of extending cuttings foreshadowing final establishments.

DISCUSSION.

The experiments described mark, it is hoped, a turning point in the long-term study of hardwood cuttings. Any new advance had to await the comprehensive study of a range of factors, and its implementation the establishment of hedge source plants to supplement the traditional nursery supplies.

Interest in hedge shoots derived from the original observations of Sinha and Vyvyan (1943) for Myrobalan B plum, that hedge cuttings compared favourably with layer cuttings and were much superior to those from newly-established nursery plants. Such excellence of hedge cuttings was surprising until it was remembered that the basal etiolated region of the layer shoots had been carefully discarded.

But if cuttings from different cultural sources root variably, so do cuttings from different parts of the same shoot, and it was in an attempt to distinguish between size and position that the Myrobalan B source experiment of 1942-43 was laid down. The results (Table I) show how considerable can be the differences in the rooting values within a clone and how complex the interactions of various factors. On the delta soil, positional advantage dominated ; basal cuttings, even of thin hedge shoots, rooted well, whereas third cuttings of layer shoots of equivalent girth rooted negligibly. These soil conditions were relatively unfavourable, as the comparative rooting values on the loam soil emphasize, and rooting behaviour of the cutting gives expression not only to its natural rooting capacity, but also to its tolerance of the environment.

Though the three varieties studied differ in level of rooting, their behaviour patterns are distinctly related, with consistent superiority of layer over hedge cutting and, with a positional gradient, the particularly strong rooting of the basal layer cutting reflects the favourable root-inducing conditions provided by previous etiolation. Even this cutting, however, by a beneficial effect of delayed separation from the layer, shows the great reluctance of Crab C to root. With the plums, excellent rooting followed both times of separation, the marked overall superiority of autumn planting indicating the benefit to previously non-etiolated cuttings of over-wintering in the soil.

One possible explanation of the marked varietal contrasts is differential speed of reaction, readiness to root being an attribute of a rapid process, shyness an attribute of a much more sluggish process. The speed of reaction is liable to vary with environment, but here all have had the same conditions, suggesting that their differences are inherently characteristic. That time may be a limiting factor is in line with the

superiority of autumn planting, while the quickening influence of growth substance treatment is also in accord.

Only a single standard growth substance treatment was applied and the experimental data indicate that this may have been too strong for the upper plum cuttings, especially those of Myrobalan B, but probably too weak for optimum effect in the apple. The use of growth substance did not overshadow the inherent varietal differences, or the source effects within the clone.

In the 1942-43 Crab C experiment, upper layer cuttings rooted negligibly in the first year but many remained alive and rooted during the second. From the main 1947-48 comparisons (Table VI) it became clear that there was a reciprocal relationship between survival and rooting, or directly stated, a quick-rooting cutting is a quick-dying one and *vice versa*. Crab C cuttings which therefore fail to root adequately may equally fail to succumb and, for such a variety, it may prove useful to exploit this survival factor by delaying taking and planting till spring and withholding pre-planting treatments. This means the consideration of two distinct and opposing potential methods, one to accelerate the rooting process so that it is sufficiently advanced to procure normal first-year establishment, the other to prolong survival to promote root development during the second season.

Brompton plum is an intermediate type which roots quite well yet can also survive to a moderate extent, especially after spring planting. Here there is no doubt that growth substance stimulation of autumn cuttings should be recommended, realizing that some may only later develop effective root systems. But, with Myrobalan B plum, the opposite extreme is reached, rapid rooting being the rule with negligible survival. With this variety the survival factor may well be limiting, for the extremely poor establishment of the apical cutting is certainly attributable to intolerance of its external environment. Indeed, it may be asked how important is the contribution of this factor to the shoot gradient effect. Thus the results of the 1942-43 experiment (Table I) show that the sharp gradient of decline up the shoot was evident only in those cuttings planted in the delta soil, and that, in the loam soil, cuttings achieved a much higher standard of rooting. Indeed, under these more favourable conditions, when the survival factor was itself probably not limiting, the thin cutting, even if from the upper portion of the source shoot, rooted more readily than the thick. Another indication of an increasing acropetal susceptibility is the differential reaction to growth substance and the lower degree of tolerance of the upper cuttings. Furthermore, whatever the variety, it is always the uppermost cutting which survives least well, and the conclusion is that behaviour depends not only on inherent capacity to root, but also on the degree of environmental tolerance.

To conclude, these experiments have shown a general consistency which gives promise for the future. The contrast in rooting behaviour between Myrobalan B and Crab C was expected, and the low rooting of non-etiolated cuttings of the latter does not detract from the general observation that layer shoots are a better source than hedge shoots. The superiority of the layer shoot resides in the root-inducing tendency of previous etiolation, but with the ready-rooting type this superiority is not always evident. This shows that, as the level rises, layer superiority diminishes and the hedge shoot becomes an excellent source, highly suited to this method of propagation. As rooting becomes inherently more difficult, however, the need for some effective stimulation to achieve early establishment becomes greater. Growth

substance treatment plays such a role and, in Brompton, has proved most effective with basal hedge cuttings, though with Crab C performance of non-etiolated cuttings is still below the 50 per cent. establishment required in the nursery. What has been observed so far is the expression of the different varietal capacities in terms of certain factor combinations, without having obliterated them by any adjustment of those factors. Growth substance treatment is one variable, soil conditions another, while a third is the natural seasonal climate, which varies from year to year, but is rarely ideal.

SUMMARY.

1. Three rootstock varieties, Myrobalan B and Brompton plums and Crab C apple, were selected as ready, moderate and shy rooting varieties respectively, for studying the rooting behaviour of hardwood cuttings.

2. In the main experiments, apical, middle and basal cuttings from layer and hedge shoots were planted in open soil, in autumn and spring, with and without a standard growth substance treatment.

3. Patterns of rooting behaviour differed in an expected manner but were distinctly related, layer cuttings being superior to their hedge counterparts, with a position gradient declining towards the shoot apex.

4. The strong rooting of basal layer cuttings was associated with root-inducing conditions when still attached to the source plant.

5. Non-etiolated cuttings of Crab C always rooted very poorly but, with the plums, autumn planting was much superior to spring planting, showing the benefit of overwintering in soil.

6. A characteristic complementary to rooting behaviour was recognized, namely, the power to survive in the unrooted state, strongest therefore in Crab C. Surviving cuttings successfully rooted in the subsequent winter dormant period. To achieve maximum establishment in this two-year method, cuttings are taken in spring and are planted without growth substance treatment.

7. The quickening effect of growth substance was insufficient to achieve first-year rooting of non-etiolated Crab C cuttings, was most beneficial with Brompton, and least necessary with Myrobalan B.

8. The behaviour of Myrobalan B showed that, when the rooting of non-etiolated cuttings is sufficiently high, the disparity between hedge and layer shoots diminishes, and hedge source plants appear to be ideal.

9. The earlier experiment with Myrobalan B showed that the rooting gradient up the shoot was determined, at least in part, by differential tolerance of the harsh environment of a delta soil. On loam this gradient was reversed when thick source shoots were used.

10. To increase the rooting of shy varieties like Crab C, further adjustment of growth substance treatment, rooting medium and seasonal climate, is necessary. The present indications are the foundations on which to build.

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PRETREATMENT OF TEA CUTTINGS FOR DISTRIBUTION BY MAIL

By W. WIGHT and P. K. BARUA
Tocklai Experimental Station, Indian Tea Association, Cinnamara, Assam

It has become the practice in north-east India to propagate tea vegetatively by means of internodal cuttings carrying only one leaf. These are prepared by the dissection of leading stems. Extensive experience shows that most of the cuttings will fail if the stems are stored for more than a few hours after being severed from the plant, even if kept moist. If the stems are dissected into cuttings their viability is further reduced. It is usual to set the cuttings in the beds immediately the stems are severed from the plant, and no practicable method has been found by which fresh material can be stored or transported for periods of more than a few hours. Leafless cuttings are of no value.

We had reason to believe that a tea cutting would become more resistant to desiccation after it had been in the propagation bed for some time. This possibility was investigated experimentally in 1945, when a total of 6,500 cuttings from three clones was set in the beds. None of the clones had been selected for ease of propagation. Commencing a fortnight after planting, samples of cuttings were drawn at intervals of fourteen days. The soil was removed from the cuttings, after which they were kept for twenty-four and forty-eight hours in wooden boxes of a standard size with loose-fitting lids. No packing was used and the conditions were such that about 20 per cent. of the green weight of the cutting was lost in twenty-four hours and about 33 per cent. in forty-eight hours. These experimental treatments were deliberately made more drastic than would be necessary in practice. Under these conditions, forty-eight hours storage was unsuccessful (Table I).

After storage in boxes, the cuttings were replanted in four replications. Eventually the final number of plants with roots and the number of first grade plants were recorded. The overall strike of cuttings was lower than would be expected from selected clones, the mean percentage of first grade plants, suitable for use in a tea garden, being 21·2 in the check, i.e. those cuttings which were not lifted at all. The three clones, however, showed the same trend.

Table I.

Percentage of good plants produced from cuttings after varying "pre-treatment" periods, followed by 24 and 48 hours drying.

Pretreatment period (days)	14	28	42	54	69	73	87	101	121	149	177	191	205
24 hours drying ..	19·1	25·8	22·5	15·8	20·8	17·5	14·2	4·2	2·5	3·3	1·7	0·8	0·8
48 hours drying ..	10·0	10·8	10·0	11·7	4·2	5·0	0	—	—	—	—	—	—

Table I shows the percentage of good plants produced from cuttings after varying periods of " pre-treatment ", the initial period in the bed prior to lifting, followed by 24 and 48 hours in wooden boxes, as already described. After from 14 to 73 days' pre-treatment the percentage of good plants varied from 15·8 to 25·8. Pre-treatment for longer periods was followed by a marked falling off in the number of first grade plants produced.

Thirty-three per cent. of the cuttings showed visible callus at the end of the first fortnight from planting and 66 per cent. were found with roots when the sixth sample was drawn after 73 days, as against only 25 per cent. drawn a fortnight earlier. Although barely visible to the naked eye, a thin layer of callus covered the base of most cuttings about a fortnight after setting in the bed.

The experiment shows that between formation of a callus layer and the emergence of roots, cuttings can be subjected to severe drying conditions without much loss of viability. This principle can be exploited in the packing of cuttings for distribution.

Subsequent experiments have shown that tea cuttings which have been pre-treated for about five weeks may be transported for considerable distances if suitably packed. In these experiments, parcels of cuttings were kept for periods of over seven days in motor vehicles in regular daily use. Moist powdered charcoal was used for packing. Provided that the time in transit did not exceed eleven days, then the pack reduced the proportion of final plants to initial cuttings to about half that obtained when the cuttings remain *in situ* in the propagation beds. The charcoal pack was used successfully for the dispatch of tea cuttings to England by air mail. The introduction of alkathene has made possible a lighter and simpler pack which does not require the use of charcoal. This method seems likely to give a proportion of plants to cuttings which will be considerably more than half that obtained when the cuttings remain in the beds, provided that the time in transit does not exceed eight days. Using either method, a pack 9 in. × 5 in. × 3 in. contains approximately 50 cuttings. In the propagation beds, these would yield 25 first grade plants of a good clone. After pre-treatment, and a duration in transit of a week, about 12 first grade plants might be expected from one pack, which is considerably more economical than any known method of transporting rooted tea plants.

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BACTERIAL CANKER OF STONE-FRUITS

I. FIELD OBSERVATIONS ON THE AVENUES OF AUTUMNAL INFECTION OF CHERRY*

By J. E. CROSSE
East Malling Research Station, Kent

THE entrance of phytopathogenic bacteria into host tissues is a comparatively simple process. Unlike many pathogenic fungi they are incapable of active penetration of protective surfaces and gain access to the host tissues either by active invasion of unprotected surfaces, e.g. non-cutinized areas or wounds, or by passive conveyance, in water, through natural openings, e.g. stomata, hydathodes.

In Bacterial Canker of cherry, caused by *Pseudomonas mors-prunorum* Wormald and by the related pathogen *Pseudomonas syringae* Van Hall (syn. *Ps. prunicola* Wormald and *Ps. cerasi* Griffin), spring and summer infection of the leaves probably takes place *via* the stomata and at any point where the cuticle has been damaged by insects. Of the avenues of autumnal infection for the canker phase on the stem and branches less is known. Here the susceptible cortical and phloem tissues are covered by a thick periderm in which the lenticels are the only permanent natural openings. Mechanical damage resulting from normal horticultural practices, e.g. pruning, cultivation, fruit picking, and possibly wounds caused by insects, such as *Anisandrus dispar* F., undoubtedly provides entrance in some circumstances (Wormald, 1932, 1937). On cherry trees, however, infections are often so numerous as to suggest that other avenues of infection are available to the pathogen.

Wormald drew attention to the lenticels as possible points of entry but in, view of the suberization of the tissues underlying these structures, it seems unlikely that infection can often arise in this way. Montgomery and Moore (1945) suggested that the pathogen entered through leaf scars during the autumnal leaf fall period. This view had much to commend it. After the leaf is detached the susceptible phloem and cortical tissues of the scar are directly exposed and active invasion would be possible at these points, provided no extensive ligno-suberization of the cells immediately underlying the abscission layer preceded leaf fall. Furthermore, it must be noted that leaf scars are exposed at a time most likely for infection, i.e. October, when for a short period the condition of winter susceptibility of the cortical and phloem tissues coincides with the presence of a copious inoculum from the leaves.

On cherry, the leaves are borne singly on the extension shoots and, on the older wood, in whorls of 5-9 at the distal end of the fruiting spurs. The inception of branch cankers via leaf scars, therefore, implies two things :

(1) on the one-year-old wood, the location of cankers at the nodes ;
(2) on older wood, the location of cankers round the base of previously infected fruiting spurs.

Both nodal and spur infections were observed by Wormald (1937), who described the development of branch cankers round the base of diseased spurs. In both types he regarded the infection as originating in the buds but Crosse (1953), who

*Part of a thesis approved for the Degree of Doctor of Philosophy in the University of London.

described similar nodal cankers on apricot, concluded that infection had taken place through the leaf scars. Webb (1950) also noted the development of cankers on cherry from previously infected fruiting spurs and suggested that most branch cankers arose in this way. But inoculation experiments provided no conclusive evidence of leaf scar infection and, from an examination of early stages of spur infections, Webb concluded that " the point of entry was not the freshly formed leaf scar, but deep cracks and crevices in the bark of the spur ".

In Bacterial Canker of cherry in the U.S.A. (*Ps. syringae*), spur and nodal symptoms similar to those described above have been reported by Griffin (1911) and Barss (1918) in Oregon, and by Wilson (1933) and Wilson and Hewitt (1939) in California. All these workers regarded the infections as originating in the buds. While the occurrence of spur and nodal infections is compatible with the idea of the leaf scar as an avenue of infection, it is clear that, although there appears to be little experimental evidence to support the view, the majority of workers regarded the buds as the original point of infection.

To determine the relative frequency of spur and nodal infections and to obtain more evidence of the mode of infection, detailed field examinations were made, over a period of four years, of natural canker infections on three different varieties of cherry. The results of these observations are described below.

Field observations of naturally occurring canker infections.

In the summer of 1949 a serious incidence of Bacterial Canker was noted on a plot of 36 four-year-old cherry trees, twelve each of the varieties Napoleon, Waterloo and Roundel, planted in a randomized block system in 1947 and arranged in three rows of twelve trees. The rows ran approximately north and south and the easterly row was separated by only a few feet from a row of mature cherry trees, forming the limit of an adjacent orchard in which the disease was rife. All three of the above varieties are susceptible, but differ in their resistance to the disease. The variety Napoleon is notoriously difficult to cultivate in some localities because of its low resistance; Roundel, on the other hand, usually suffers much less from the depredations of the disease, while Waterloo is approximately intermediate in resistance between the other two.

In 1949, a total of 343 dead spurs were recorded on these trees and round the base of 225 of these were branch cankers. From the necrotic tissues of these spurs *Ps. mors-prunorum* was consistently isolated. The varieties Napoleon and Waterloo were severely diseased, but on Roundel only 12 dead spurs were found, 6 of which were situated at the centre of branch cankers.

In 1950 and the following two years, canker infections on these trees were examined in detail. Observations were made towards the end of May when the young leaves were just fully expanded and the infections noted were classified into three distinct groups, viz. :

(1) those associated with wounds and mechanical damage to the periderm (wound infections).
(2) those occurring at the nodes on one-year-old wood (nodal infections).
(3) those associated with fruiting spurs (spur infections).

Samples of the three types of infection were taken and the cause established by the isolation of *Pseudomonas mors-prunorum*.

PLATE I

Fig. 1.

Partially diseased nodes on one-year-old branch of Napoleon cherry. All except the lowest nodes on the two outside branches were infected in the leaf scars subtending the buds. Note the varying degrees of delayed bud development. Some of the infected nodes were hardly distinguishable from the healthy ones. At one node, indicated by the arrow, gum was exuding from the diseased leaf scar tissues.

Fig. 2.

Fruiting spurs on a three-year-old branch of mature cherry (variety Schrecken). Those indicated by arrows had micro-cankers in one or more of the leaf scars, which in Spur B were sufficiently extensive to have caused collapse of the spur soon after blossoming. Note dead buds on Spurs C and D and the reduced leaf size of Spur C.

Fig. 3.

Diseased fruiting spur on the variety Napoleon. The central leaf bud had failed completely; two flower buds developed but withered shortly after the blossoming.

[face p. 132

PLATE II

FIG. 4.

Three-year-old branch of Roundel cherry showing two healthy and two dead spurs. The infection had proceeded no further than the base of the dead spurs and there was no sign of branch cankers.

FIG. 5.

Cherry branches showing cankers (outlined in white) which have developed from previously infected fruiting spurs (indicated by arrows).

Left : Note copious gum round infected spur. The canker has progressed up the branch, cutting off an otherwise healthy spur which has collapsed in full leaf.

Right : This canker resulted from the infection of two spurs and girdled the branch, causing a wilt of the distal parts.

1. *Wound infections.*

The majority of these had taken place through natural growth crevices at stem and branch unions ("crotch" cankers). Occasionally infection was associated with mechanical damage resulting from pruning and cultivation and, rarely, with cracks in the periderm along the margin of an old canker. On the one-year-old wood a few internodal cankers were observed in 1952, all of which were located round small punctures presumably caused by insects.

2. *Nodal infections.*

Diseased nodes could be arranged in a continuous series differing in the extent of the internal necrosis (Fig. 6). In the milder forms this was limited to the tissues immediately under the leaf scar subtending the bud, where it was sometimes entirely confined to one or more of the three vascular traces of the old leaf base, down which it extended for distances varying from 1 to 5 mm. More commonly, however, the parenchymatous ground tissues surrounding the traces were involved to a greater

Fig. 6.

Diseased spurs (1–5) and nodes (6–9) on cherry, caused by *Pseudomonas mors-prunorum*. The shaded areas show the extent of the necrosis. Note the extremes from spur canker (1), to partially diseased spur, where the necrosis in the leaf scar (see arrow) is too small to affect normal development of the buds (5).

7a–9a are views of infected nodes from above. For the sake of clarity the buds are not represented. Note localization of infection to vascular strands of the leaf traces (8a and 9a).

or less extent. In these less severely diseased nodes, the buds were still healthy but their development was retarded to varying degrees, depending on the extent of the associated necrosis. When this was slight, the bud was often fully expanded although in such instances the young leaves were slightly smaller than normal ; with the more extensive necroses, bud development had usually proceeded little further than swelling (Fig. 1).

In the most severely diseased nodes, the buds had been killed and were surrounded by discrete cankers on the branch which sometimes extended downwards as far as the next node (Fig. 6). Many of the buds had swollen before being invaded, suggesting that they had not become involved in the general necrosis until a comparatively late stage. In the varieties Napoleon and Waterloo these nodal cankers frequently girdled the twig and eventually resulted in die-back.

3. *Spur infections.*

Diseased spurs formed a series similar to the nodal infections (Fig. 6). In those slightly diseased, the necrosis was again limited to the tissues immediately under the leaf scars, where it was often confined entirely to the vascular strands of the leaf traces. There was the same general correlation between extent of the necrosis and the degree of retardation or suppression of bud development. As each spur carried from 1 to 5 buds and from 5 to 9 leaf scars, the external symptom picture they presented was more complex than the diseased nodes and depended on the number of scars infected. Thus only one or two of the buds might be affected and the remainder develop normally (Fig. 2). Occasionally only a flower bud developed ; the spurs then presented an unusual appearance carrying flowers but no leaves (Fig. 3). In a few spurs an extensive necrosis was located in the heart of the spur at some distance below the leaf scars, but this was invariably connected to a scar by a more restricted necrosis of the vascular strands. In these examples the development of all the buds on the spur was usually suppressed, although the actual bud tissues themselves were still healthy. Sometimes one side of a spur, including a bud, was completely dead, while the other side was still healthy and with the buds normally developed or only slightly retarded (Fig. 6). On the most seriously diseased spurs all the buds were dead (Fig. 4) and the infection had often spread from the base of the spur to the branch tissues, resulting in cankers (Fig. 5). These cankers were often extensive on the variety Napoleon and caused widespread die-back of the branches.

The leaf scar as an avenue of infection.

A range of spur and nodal symptoms apparently similar to those described above were reported from Oregon by Barss (1918) who attributed them all to infection of the buds by insect disseminators of the disease. Death of the entire spur resulted only if buds were infected in the winter but, with later infection in early spring, the buds might actually open and the blossom expand, to wilt and die soon afterwards.

The idea of bud infection in the present case was clearly incompatible with the evidence. Even where spurs were completely dead, the buds had often begun swelling before being killed, and it was clear they had become involved only in the later stages of the disease. This indicated some place other than the bud as the original point of infection. The distribution of necrosis in the less severe forms suggested that infection had taken place through the leaf scars. This conclusion was subsequently confirmed experimentally by the inoculation of leaf scars in the autumn, as a result

of which symptoms developed the following spring indistinguishable in range of form and intensity from those occurring naturally. A short account of these experiments has already been published (Crosse, 1951).

The seasonal and varietal incidence of wound cankers, and diseased spurs and nodes.

In early summer, for three successive years, the incidence of wound cankers and diseased spurs and nodes was recorded. The varietal and seasonal distribution of these is shown in Table I. The years shown are those in which the records were made, the infections recorded having been established the previous autumn. For spurs only, the character of the final disease symptoms and the total number of spurs on the trees were also recorded.

The majority of the infections observed were leaf scar infections of the spurs and nodes. Most of the wound infections were "crotch" cankers at branch unions or branch and stem unions. Waterloo was particularly susceptible to these and, by 1951, so many trees had been killed or severely mutilated in this way that further recording of the variety was abandoned. The progressive and more or less uniform increase in wound cankers over the three-year period suggested that their incidence was closely related to tree size. On all three varieties considered together, there was also a progressive yearly increase in the number of diseased spurs attributable in part perhaps to the increasing number of spurs becoming available for infection. The high incidence of diseased spurs on Napoleon and Roundel in 1952, however, was out of all proportion to the increase in tree size. The numbers of diseased nodes showed no correlation at all with tree size.

The total and relative seasonal incidence of diseased spurs and nodes on the three varieties was extremely variable. On Waterloo and Napoleon, for example, the number of diseased spurs was approximately the same in 1951 as in 1950 but the number of diseased nodes fell markedly, particularly on Waterloo. Roundel, on the other hand, showed an increase in both types of infection in 1951 compared with 1950, the increase for diseased spurs being nearly fivefold. In 1952 there was a steep rise in the number of diseased spurs on Roundel and Napoleon ; at the same time there was an increase in the number of diseased nodes on Napoleon, but a decrease on Roundel.

It was clear that there was no consistent relationship between the numbers of diseased spurs and nodes occurring on the varieties from year to year. The varieties and the spurs and nodes, therefore, behaved independently in relation to infection. There are two possible explanations of this, namely, (1) annual and varietal differences in the amounts of the leaf inoculum available for autumnal infection, and (2) differences in the times of maximum infectibility of the varieties and of the spurs and nodes.

Experiments, to be described elsewhere, have shown that concentration of inoculum is an important factor in leaf scar infection. Differences between the varieties in the relative amounts of leaf inoculum available from year to year may, therefore, have accounted for some of the variation observed in the incidence of infections. If this were the only factor involved, however, it would be expected that the numbers of diseased spurs and nodes occurring each year on individual varieties would be constantly related, since the spurs and nodes on each variety were always exposed to the same relative amounts of inoculum. The fact that no such relationship was observed suggests that the second of the above explanations is the more likely one.

TABLE I.

Annual frequency of wound cankers and diseased spurs and nodes on three cherry varieties over a period of three years (average number per tree).

Variety	No. of trees recorded	1950			No. of trees recorded	1951			No. of trees recorded	1952		
		Wound cankers	Diseased spurs	Diseased nodes		Wound cankers	Diseased spurs	Diseased nodes		Wound cankers	Diseased spurs	Diseased nodes
Napoleon	12	0·2	15·0	11·4	8	1·0	14·8	5·3	12	1·6	65·6	10·8
Waterloo	10	0·5	8·0	13·5	7	1·3	7·6	0·9	—	—	—	—
Roundel	12	0·0	2·0	2·2	8	0·1	9·6	2·5	12	1·6	78·5	1·2
All varieties	32	0·2	8·4	8·9	23	0·8	10·8	3·0	24	1·6	72·0	5·9

The infection of a leaf scar will depend on the following three contingencies :

(*a*) the abscission and fall of the leaf,
(*b*) the arrival of an infection drop on the leaf scar,
(*c*) the susceptibility of the leaf scar to infection.

General leaf fall in cherry, indicated by a more or less simultaneous yellowing and abscission of the leaves, usually begins towards the end of October or beginning of November, depending on the season. Prior to this, however, there is a sporadic fall of occasional leaves beginning sometime in September, so that leaf scars are actually exposed over a long period. In summer the progress of over-wintered cankers resulting from infection the previous autumn is halted and the bacteria die out on the infected tissues. At this stage, according to Wormald (1937) and Barss (1918), the susceptibility of the stems and branches to infection is low. During the autumn, however, susceptibility increases and the bark again becomes highly liable to infection. The physiological changes associated with this latter process do not necessarily run parallel in varieties, since they differ in the time of general leaf fall. At any given stage, therefore, the liability of leaves to detachment and of scars to infection may not be the same in different varieties. A similar difference may exist between nodes and spurs, since nodal leaves usually fall before those on the spurs. If this view is correct, then the relative levels of varietal and spur and nodal infections will be determined to a large extent by the distribution of infective conditions, e.g. rain and high winds, during the autumnal period. On this basis, for example, the low numbers of diseased nodes on Waterloo and Roundel in 1951 and 1952 respectively could be attributed to the absence of rain at a time when the nodes of these two varieties were at the stage of maximum infectibility. This concept of rain distribution as a factor in infection in nó way detracts from the importance of total rainfall during the autumn. It is suggested, however, that while total rain may decide the general level of canker infection, varietal performance is mainly determined by the distribution of rain during the infection period.

Strong winds, which are also characteristic of the autumnal period, are obviously another important factor in leaf scar infection and the distribution of these, particularly in relation to rainfall, may also influence the relative levels of infection occurring on the different varieties.

Severity of the disease.

In addition to numbers of diseased spurs, i.e. to the incidence of the disease, there were also differences between the varieties in the severity of the disease, as shown by the nature and intensity of the resulting symptoms and the extent of the associated necroses.

In spur infections a quantitative estimate of these differences in disease severity was obtained as follows :

Diseased spurs were placed into one of the following three categories :

(1) spurs completely dead, with the infection spread to branch tissues (spur canker).
(2) spurs completely dead but with the infection spread no further than the base of the spur (dead spurs).
(3) spurs only partially diseased, with one or more of the buds still healthy (partially diseased spurs).

To these categories arbitrary disease ratings of 5, 3 and 1 respectively were assigned. For each year the varietal total and mean disease ratings were then calculated.

The mean disease rating was a measure of the seriousness of the final disease symptoms and was termed the *disease severity index.*

The severity of the disease was compared with the incidence of the disease. Because of their lower vigour and severe depredations of the disease, the trees of Napoleon and Waterloo were slightly smaller than Roundel. Disease incidence was measured, therefore, as the number of diseased spurs expressed as a percentage of the total spurs on the trees.

Severity indices and percentage spurs diseased are shown in Table II.

TABLE II.

Percentage spurs diseased and severity indices on three varieties of cherry.

Variety	1950		1951		1952	
	% Spurs diseased	Severity indices	% Spurs diseased	Severity indices	% Spurs diseased	Severity indices
Napoleon	5·22	3·99	1·78	3·66	8·15	3·34
Waterloo	3·35	3·04	0·99	3·04	—	—
Roundel	0·73	3·18	1·06	2·92	6·91	2·78

In all three years both incidence and severity were highest on the variety Napoleon. The greater disease severity on this variety was due to the fact that infection ultimately spread to the branch tissues from far more diseased spurs than in the other two varieties. The position of the variety Waterloo in regard to disease severity was somewhat anomalous. Thus, in 1951, it was intermediate between Napoleon and Roundel, whereas in 1950 it was lowest. In both years several of the trees were dying from stem cankers originating in branch and stem unions, and this may have affected the symptoms developing from the spur infections, but the evidence on this point is inconclusive.

The relationship between incidence and severity in diseased spurs.

This is shown for the varieties Napoleon and Roundel in Fig. 7.

Incidence varied widely with season and independently on the varieties, a phenomenon which has already been noted and attributed to the distribution of infective conditions in the autumn.

Severity did not vary in the same way and appeared to be independent of disease incidence. Since the severity of the disease must to a large extent depend on the rate at which the pathogen spreads through the host tissues, the fairly constant relationship between the severity indices of the varieties suggests the operation of some uniform resistance factor, inherent in, and characteristic of, the tissues of each variety. This factor, or the effects of this factor, appeared to increase slowly and proportionately in the varieties as the trees increased in age,

except on Waterloo (cf. Table II) where it remained unaltered over the two years in which this variety was recorded.

The fact that incidence as well as severity were consistently higher for Napoleon than for Roundel suggests that inherent resistance factors may also influence the rate of infection.

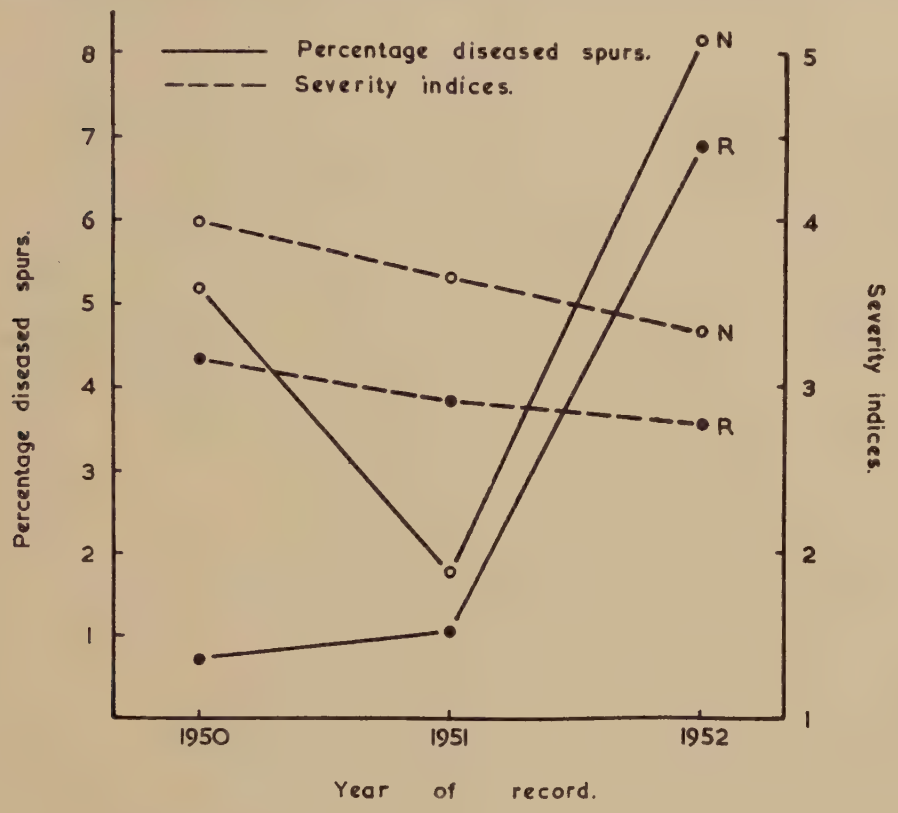

Fig. 7.

Diagram illustrating the relationship between disease incidence and disease severity (measured as percentage diseased spurs and severity indices respectively) for spur infections on the two cherry varieties Napoleon and Roundel from 1950 to 1952 inclusive.

DISCUSSION.

The observations described above have shown that leaf scars are the main avenue for autumnal infection. Most of the branch " die-back " on Napoleon and Roundel was caused by this type of infection. Waterloo suffered in the same way but, on this variety, the effects of leaf scar infection were to some extent overshadowed by the extensive " die-back " resulting from crotch cankers.

Partially diseased spurs and nodes, where the buds themselves were still healthy, have not hitherto been recorded in Britain. In some of these the necrosis in the leaf scar area and its effect on subsequent bud development were so slight that, apart from difference in leaf size during expansion, they were indistinguishable from healthy

spurs and nodes and, after the sealing off of the infection in early summer, continued normally.

The number of partially diseased spurs and nodes on the trees may have been greater than the records indicate. They were not always easy to distinguish from healthy spurs and nodes and many, where the necrosis in the leaf scar area was too small noticeably to affect bud development, may have remained undetected. This implies the possible existence of symptomless or virtually symptomless infection.

The discovery of partially diseased spurs and nodes may to some extent explain a problem connected with the transmission of the disease from the nurseries. Instances are known of trees, apparently healthy when they left the nursery, eventually succumbing to the disease after transplantation to localities where the chances of outside infection were extremely remote. Montgomery (Moore, 1946) has suggested that the pathogen may be carried from the nursery at or near the surface of the buds where it may have over-wintered saprophytically. Crosse and Bennett (1955) have shown that *Pseudomonas mors-prunorum* can in some circumstances survive several months on the bud surfaces, but there is no direct evidence that the pathogen is ever carried from the nursery in this way. An alternative suggestion now is that the pathogen may sometimes be carried in a pathogenic state in incipient leaf scar infections, symptoms of which may never be detected. The assumption that trees are healthy when they leave the nursery, therefore, may often be false.

By normal standards of field assessment, the incidence of the disease on the observational plot over the three years was severe. Despite this it will be noted that the highest incidence of diseased spurs recorded was only 8·15 per cent., although the actual figure may have been higher if the possibility of symptomless infection is taken into account. Since each diseased spur may have been invaded through only one of its seven or more scars, it was evident that only a very small proportion of the total leaf scars exposed became infected. Some scars no doubt were exposed in dry windy weather when the absence of rain precluded infection. But the majority were formed during the general leaf fall at the end of October and in all three years conditions were highly favourable for infections at some time or another during this period. It is thus difficult to believe that many spurs could have escaped the arrival of an infection drop on one or other of its scars. It is possible to conclude from this that scars exposed during the period of general leaf fall may not be very liable to infection. Considerable support for this view has since been derived from leaf scar inoculation experiments.

The three varieties in the observational plot behaved in accordance with previous field experience. The greater " field resistance " of Roundel appeared to be due to two distinct, but not necessarily unrelated factors, viz. the greater inherent resistance of its tissues to the spread of infection and its lower liability to infection.

The behaviour of the three varieties in relation to the disease raises the question as to what criterion is to be used in assessing varietal resistance. On the basis of tree mortality, for example, the variety Waterloo, due entirely to its extreme liability to crotch infection, was undoubtedly the least resistant. If, on the other hand, the severity of the disease symptoms and branch " die-back " resulting from leaf scar infections of the spurs were compared, then Waterloo was more resistant than Napoleon. In his studies of Bacterial Canker of stone-fruits in California, Wilson (1939) also drew attention to the various criteria which could be used for assessing resistance under field conditions and mentioned in particular frequency of infection,

tree mortality and rate of canker extension through the tissues after infection. While it is true, as Wilson suggested, that it is the total effect of these various aspects which must form the basis for assessing " field resistance ", it is nevertheless important that a distinction be made between them when one is considering the factors underlying resistance phenomena.

SUMMARY.

Canker infections on cherry were found to be associated with wounds, fruiting spurs, and with the nodes on one-year-old wood. Evidence was found of the infection of spurs and nodes through leaf scars. Most branch cankers arose from the leaf scar infection of fruiting spurs.

The annual and varietal distribution of diseased spurs and nodes indicated that varieties, and spurs and nodes, behaved independently in relation to infection ; reasons for this are discussed.

The incidence of diseased spurs varied widely with season, but the expression of the associated symptoms was fairly uniform and appeared to be characteristic mainly of the variety.

The results of these field observations are discussed in relation to disease transmission, autumn infection and varietal disease resistance.

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BOOK REVIEWS

THE PESTS OF FRUITS AND HOPS. By A. M. Massee. (London : Crosby Lockwood. 1954. 3rd edition. Pp. 338, illus. Price 25s.)

The many readers who are already familiar with the earlier editions of Dr. Massee's book will note with satisfaction that, not only have the results of the recent extensive researches of his Entomology Section at East Malling Research Station been skilfully incorporated into the text, but also the changing concept of the orchard as a carefully balanced habitat, in which harmful and beneficial insects struggle for supremacy, is boldly advanced. The grower who is a true countryman and formerly learned to live with the pests of his crop, must now go to great lengths to learn to live without them. He should know the basic facts of insect metamorphosis which lie behind the apparently sudden and mysterious visitations, the broad effects of weather conditions on the different stages and the role of parasites and predators. Dr. Massee is a past master in the art of rendering such knowledge palatable to the grower and scientist alike.

The book is arranged, as were the earlier editions, under the broad headings of host crops, each pest being dealt with by a short statement of its appearance and status, followed by eminently practical and valuable directions for field recognition. The completed life cycle is then stated and the control measures, predominantly chemical, are built up on this basis.

The changing picture of pests in the orchard and fruit garden during the past 10 years is revealed. On the credit side, Apple Blossom Weevil has slid from near the top to the bottom of the pest list, together with Winter Moth and the Apple Capsid, which is now regarded by Dr. Massee as being virtually eliminated from commercial orchards in Britain. Other successes in chemical control have been scored against the Hop Aphids and Red Spiders and against the Strawberry Aphid. On the debit side of the account, the Fruit Tree Red Spider Mite has become more prominent, particularly in Essex, and the Codling Moth continues to present a difficult control problem. The lessons of the expanded chapter dealing with Beneficial and Harmless Insects should be carefully read and appreciated by grower, naturalist and specialist alike.

There are special sections of the book on Insecticides by R. P. Tew and on Spraying Machinery by Geoffrey Fletcher which are authoritative and informative. A reference, on page 270, to the Crop Protection Approval Scheme of the Ministry of Agriculture and to the importance of formulation is particularly useful. An attempt (page 291) to set a standard in describing the output of spraying machinery is welcome.

Some words of criticism of the text as a whole must, however, be offered. The reader who is not a biologist would have welcomed a short introductory chapter outlining the distinctive characters of insects and mites, with some illustration of the facts of metamorphosis and of the features shown by the immature stages.

The quotation of the scientific family name of each pest and the separation in the text of the Orders would have avoided a certain confusion in the reader's mind. For instance, we pass on page 62 *et seq.* almost imperceptably, *via* the Apple Leaf

Skeletonizer, from the Lepidoptera to the Hymenoptera represented by the Apple Sawfly.

More important, however, is the question of expressing quantities and concentration of recommended insecticides—the bugbear of authors who must necessarily preserve the anonymity of useful products. Here it is easier to offer destructive rather than constructive criticism. In most places, it is true, the original strength of a formulation is quoted, in others it is not clear whether the percentage quoted represents active ingredient or formulated product. Could we not accustom ourselves to a system of quoting the amount of active ingredient per acre, the conversion for formulation and rate of application being relegated to a table in the section on Insecticides ?

In the Insecticide section, the reader would like to sense a more intimate relation with the pest in the orchard. Spray programmes are nowhere stressed or, if obsolete, criticized. The ideal of meeting each pest as it occurs is far from attainment. In permanent crops such as fruit trees, spraying is, in the long term, prophylactic and one would like to have seen a fuller discussion of the pattern of pests and existing spray programmes in different fruitgrowing areas. The progressive reduction of over-elaborate schedules, which is so warmly advocated by Dr. Massee on biological grounds, could then be stated in practical terms. Unless we can turn the fruitgrower into a biologist, rules of thumb must continue for many years to play an essential part in orchard spraying.

These remarks, however, when added up, do little to detract from the Golden Treasury of sound practical advice to the fruitgrower and horticulturist which Dr. Massee's book provides. Dr. Greenslade's admirable photographs add greatly, as before, to the enjoyment and easy understanding of the text.

W.F.J.

THE NEW ZEALAND GARDENER. TENTH ANNIVERSARY ISSUE. (Wellington : A. H. and A. W. Reed, 182 Wakefield Street. 1954. Pp. 132, illus. Price 1s.)

We have received with pleasure a copy of the tenth anniversary issue of this useful and popular Journal. As Sir Theodore Rigg, Director of the Cawthron Institute, says in his congratulatory message : " *The New Zealand Gardener* makes a valuable contribution to horticulture and gardening in New Zealand. It covers a great variety of subjects, both from a practical and scientific viewpoint." A glance through the pages of this issue is sufficient to endorse the truth of this statement. We congratulate our contemporary and wish them all success in the future.

T.N.H.

STATISTICS AND MATHEMATICS IN BIOLOGY. Ed. by O. KEMPTHORNE, T. A. BANCROFT, J. W. GOWEN, and J. L. LUSH. (The Iowa State College Press. 1954. Pp. ix+632. Price $6.75.)

This book consists of 44 papers, these being a selection from those offered at the " Biostatistics Conference ", held in June–July, 1952, at Iowa State College.

It is divided into five sections headed : (I) General biometrical principles and

procedures, (II) Changes in population number, (III) Estimation of populations, (IV) Determination of biological response, and (V) Genetical analysis of populations. Section I has a paper by E. Anderson on " Efficient and inefficient methods of measuring specific differences ", which raises and goes some way towards solving the question which faces every biologist applying quantitative methods to his material, namely, how to find the characters to measure which are most relevant to the experimental situation. Until this question is answered, none of the multivariate analysis methods ably summarized in five other papers in this section will avail much. In Section II a paper by T. Park, describing a laboratory experiment on the effects of competition between two closely related species of flour beetle, underlines the complexities to be accounted for in any mathematical theory of population dynamics. The populations considered in Section III are mostly of a kind not likely to be of direct interest to readers of this journal, though there are two papers of general interest by D. B. Delury and O. Beall on the assumptions underlying estimates of mobile populations, and data in binomial and near-binomial distributions, respectively. Section IV treats a miscellaneous collection of subjects, of which bioassay and food flavour assessment are of interest here. Cornfield contributes a careful review of the adequacy of the mathematical background of bioassay which is a model of clarity ; Dews and Berkson discuss the difficulty of assigning standard errors to absolute standards, as distinct from the relative effects measured in most experiments. Their analysis is marred by their not realizing that the problem had been formulated and discussed by " Student " some 30 years ago. The two papers on sensory tests with foods give a useful summary of progress up to now.

The genetical analysis of populations covers an enormous field which the papers in Section V reflect—they include a paper by Bruce Griffing on some gene-environment interactions in tomato which should be of interest to plant breeders.

This book raises in an acute form the question of the usefulness of symposia. The Editors in their preface state that the Conference was " intended to advance the unified approach to biological problems by bringing together on each of many topics a biologist and a statistician, or a mathematician". After reading this book one is left feeling that " the unified approach " is still a very long way off, and this is accentuated by the enormous variation in the levels of generality and detailedness in the contributions. Perhaps the greatest gap is the lack of any usable mathematics of organization, without which, one feels, the statistician and biologist will continue to talk different languages, to their mutual disadvantage.

The book is well produced and printed and only a very few trivial misprints have been noted.

J.A.N.

THE BROWN ROT DISEASES OF FRUIT TREES. By H. Wormald. Technical Bulletin No. 3, Ministry of Agriculture and Fisheries. (London : H.M.S.O. 1954. Pp. 113, illus. Price 5s. net.)

As would be expected by those who know Dr. Wormald, or are familiar with his own distinguished contributions from Wye College and East Malling Research Station to our knowledge of the Brown Rot diseases, this Bulletin is first-class. Some indication of its scope as a compendium of information from world literature

may be gauged by a glance at 28 pages of over 900 references, a large proportion of which are drawn upon for the text. The impression given by the whole work is one of characteristic thoroughness, accuracy, and authoritative grasp of the subject. Though the Bulletin is intended chiefly for specialists in the plant pathology field (hence its publication in the Ministry's Technical Series), it is no overstatement to add that everyone concerned with the practice of fruitgrowing will find something of interest and help in its pages. It supersedes an earlier Bulletin (No. 88) on the same subject, also written by Dr. Wormald, and published by the Ministry some 20 years ago. The increased scope of the present monograph reflects increasing recognition of the serious nature of the losses due to the Brown Rot diseases. This is to be seen in comprehensive additional sections on laboratory investigations to discover fungicides of merit chiefly in preventing spore-germination, and on the use of such materials, and others, in controlling the diseases in the field. Such work as has already been done in the relatively new antibiotic field also receives attention.

In spite of this intensive attack from research workers in many parts of the world, the Brown Rot diseases, when seen against a background of great all-round improvement in pest- and disease-control during the past two decades, still tend to be regarded in practice as an annual visitation to be suffered with resignation. This insidious fungal family has a wide host-range, and commands almost fantastic powers of fecundity and dissemination by spores. These are contributory reasons, but the chief one, more particularly as regards the fruit-rotting members, is undoubtedly that they are most commonly wound-pathogens in the plantation and are therefore not consistently amenable to the usual control measures by protective sprays. A fresh wound provides a fresh port of entry, and any potential merit of protective fungicides—and those that show promise on glass slides in the laboratory are not lacking—is largely vitiated in practice by these vulnerable breaks in the protective layer of spray on the host-plant. That is not to imply that the problem of control is insoluble ; far from it, but, as the Bulletin makes clear, that success is likely to be limited. Much can be done by measures of general hygiene, by control where possible of wound-forming agents and, in some cases at any rate, by spraying or dusting. In large-scale practice, however, and especially with some host-plants, a point is reached beyond which it may well prove uneconomic to go.

For the rest, the Bulletin is arranged clearly in sections covering the history, geographical distribution, classification and nomenclature, morphology and cytology, and the culture, physiology and biochemistry of the Brown Rot fungi, their mode of entry into the host-plant, the conditions conducive to infection and the losses caused. These sections follow the general pattern of the earlier Bulletin, but with some improvement in presentation and with added material. Apart from the extensive bibliography, nearly one-third of the text is devoted to a description of each individual disease under its principal host-plant—a very valuable part of the whole for the plant pathologist and also the fruitgrower. The general principles of control measures, as distinct from the details to be found in the preceding pages, are admirably brought together in a short concluding section.

Mention of the Bulletin would not be complete without references to the excellent plates—a tribute for the most part to its author's skill as a photographer.

At five shillings this Bulletin represents exceptional value in these days.

M.H.M.

CONSERVATION PAR LE FROID DES DENRÉES D'ORIGINE VÉGÉTALE. By R. Ulrich. (Paris : Librairie J.-B. Baillière et Fils, 19 Rue Hautefenille. 1954. Pp. 328, illus. Price 2,500 francs ; including postage, 2,745 francs.)

It is a great help to a reviewer if the author indicates, in the preface, for which type of reader the book has been written. The author of this work gives us no such assistance. But, whatever his intention may have been, he has produced a first-class textbook for the new generation of refrigeration engineers (who too often neglect the biological needs of the produce to be stored) and managers of cold stores, who are being trained in colleges of refrigeration in many European countries.

It is not surprising to find that a book by a Frenchman is written to a logical plan ; Ulrich considers first of all the general biological phenomena which have a bearing on the behaviour of plant products in cold storage, the effects of low temperature on vegetable tissue, the practical use of refrigeration and finally detailed discussion of the application of refrigeration to different varieties of fruits and vegetables. The work is rounded off by bringing flowers, whole plants and plant products into the picture.

The author would not claim that his book was written for the specialist research worker. Nevertheless, the number of such workers is limited, and their interests often intensely specialized ; this book will be frequently consulted in their laboratories. The bibliography alone is worth the cost.

I cannot see the book being very valuable to operators of cold stores in this country. This is a reflection on them, and not on the author. Things may be better in France, but it is my experience that instructions to cold store managers must be simple and direct and that it cannot be emphasized too often that the history of the produce before it arrives at the store greatly influences the behaviour in storage.

Professor Ulrich is a distinguished scientist, professor at the Sorbonne and director of the refrigeration research station at Meudon. This book will enhance the already high opinion of his work, better appreciated on the Continent than here. The typical French paper back to the book is a pity ; I doubt if it will long endure the constant reference which at least one of Professor Ulrich's English colleagues will give it.

J.C.F.

THE SOILS OF THE WEM DISTRICT OF SHROPSHIRE. By E. Crompton and D. A. Osmond. (London : H.M. Stationery Office. 1954. Pp. 79, illus. Price 10s. 6d.)

The soils of an area of 216 square miles lying mainly in North Shropshire are mapped and described.

The soil map, presented at a scale of 1 inch to 1 mile, has been coloured to make it easy to recognize immediately the major soil groups. Knowing these major groups, useful information can be gained about the water relationships of the soils without knowing the characteristics of the more numerous soil series.

The major soil groups are described as well as the individual soil series, the latter including soils varying from light sands to the heaviest clays. Analytical data, typical of each series described, are also included.

A most interesting section on the agricultural history of the area is followed by an account of the present-day agricultural practices in the region which have

developed into a balance between arable cropping and stock farming with little or no market gardening and fruit growing.

This publication is the first of a series of memoirs which are intended to describe the soils of the whole of England and Wales. As the first, it forms an admirable pattern for those to follow.

J.E.G.

PUBLICATIONS RECEIVED.

THE NATIONAL INSTITUTE OF AGRICULTURAL BOTANY THIRTY-FOURTH REPORT AND ACCOUNTS, 1953. (Cambridge : National Institute of Agricultural Botany. 1954. Pp. 48.)

AMATEUR GARDENING DIARY AND HORTICULTURAL DIRECTORY, 1955. (London : W. H. and L. Collingridge Ltd. 1954. Pp. 160. Price 6s. 2d.)

FRUITS, VEGETABLES AND FLOWERS. By G. M. KESSLER. (Minnesota : Burgess Publishing Co., 426 South Sixth Street, Minneapolis. 1954. Pp. 67, illus. Price $2.00.)

NOTICE TO CONTRIBUTORS

1. The **Journal of Horticultural Science** is an official organ of the Horticultural and Agricultural Research Station, Long Ashton, Bristol, and the Horticultural Research Station, East Malling, Kent.

The Publication Committee welcome horticultural papers from all other sources.

2. All **manuscripts** should be in double-spaced typewriting, with a good margin, and should be addressed to the Editors, East Malling Research Station, near Maidstone, Kent, England. Papers must be written concisely. Historical reviews should be as short as possible and only such references to literature as bear directly on the subject should be included. Tables and illustrations, if any, must be only such as are absolutely essential for clear presentation.

3. Authors of papers containing extensive **numerical observations** should consult the recommendations of the British Association Committee on Biological Measurements, 1927, obtainable from Burlington House, London, W.1. Price 6d. Arrangements have been made whereby original data too extensive for complete publication may be deposited at the British Museum (Natural History), London, S.W.7, or with the Royal Society of Edinburgh, 22 George Street, and thus be available for consultation by other workers. Full bibliographical reference to the publication in which the results are summarized must be supplied with the data.

4. Each paper must conclude with a concise and critically correct **summary** of its actual content. It should contain any new or verified constants as well as any other critical data of permanent value but not tables or graphs. Any organism mentioned should be given its scientific name.

5. Where a paper is of a highly technical nature it should be preceded by a brief **synopsis**, in which its contents are simply and clearly stated for the benefit of non-technical readers.

6. **References to literature** may be by numbers (in brackets) in the text corresponding to a numbered list at the end of the paper or by the Harvard system (author's name and date of publication). By either method, the papers cited should be listed alphabetically according to authors' names, followed by the date of publication. The title of the paper should next be given in full, followed by contracted, but strictly intelligible, title of source of publication, the volume and page numbers. Authors are responsible for the accuracy of their lists of references and should check them carefully in both typescript and proof.

7. The **scientific names** given in the "List of Common British Plant Diseases", published by the British Mycological Society (Cambridge University Press, 1944) and "Common Names of British Insect and other Pests", published by the Association of Applied Biologists (The Mendip Press Ltd., Bath, 1947) must be employed.

8. Authors in this country will be supplied with slip **proofs** of their papers; these they should correct with care immediately on receipt and return without delay, together with the original manuscript. Page proofs are not usually supplied to authors. Typographical errors, if any, should be corrected; small verbal alterations are permissible but substantial changes may not be made. Overseas authors should be willing to accede to editorial treatment of their contributions, if necessary, limited to methods of presentation, and leave proof correction to the Editors.

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CONTENTS

	PAGE
Observations on the Raspberry Cane Midge (*Thomasiniana theobaldi* Barnes). III. Control. By R. S. PITCHER..	73
The Influence of Orchard Nutrition upon the Acidity Relationships in Cortland Apples. By C. A. EAVES and J. S. LEEFE..	86
Some Factors Affecting the Balance of Phytophagous and Predacious Mites on Apple in South-East England. By ELSIE COLLYER and A. H. M. KIRBY	97
Plant Growth Regulators. I. The Influence of Side-chain Length on the Activity of ω-(2-naphthyloxy)-*n*-alkylcarboxylic Acids for the Induction of Parthenocarpy in Tomatoes. By L. C. LUCKWILL and D. WOODCOCK	109
The Influence of Source and Growth Substance on the Behaviour of Apple and Plum Cuttings. By R. J. GARNER and E. S. J. HATCHER	116
Pretreatment of Tea Cuttings for Distribution by Mail. By W. WIGHT and P. K. BARUA	129
Bacterial Canker of Stone-Fruits. I. Field Observations on the Avenues of Autumnal Infection of Cherry. By J. E. CROSSE ..	131
Book Reviews	143

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